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BASIC REQUIREMENTS FOR MANUSCRIPTS

Original papers and discussions of current papers should be submitted to the Manager of Technical Publications, ASCE. Authors should indicate the technical division to which the paper is referred. The final date on which a discussion should reach the Society is given as a footnote with each paper. Those who are planning to submit material will expedite the review and publication procedures by complying with the following basic requirements:

1. Titles must have a length not exceeding 50 characters and spaces.

2. A summary of approximately 50 words must accompany the paper, a 300-word synopsis must precede it, and a set of conclusions must end it.

3. The manuscript (an original ribbon copy and two duplicate copies) should be double-spaced on one side of 8½-inch by 11-inch paper. Three copies of all illustrations, tables, etc., must be included.

4. The author's full name, Society membership grade, and footnote reference stating present employment must appear on the first page of the paper.

5. Mathematics are recomposed from the copy that is submitted. Because of this, it is necessary that letters be drawn carefully, and that special symbols be properly identified. The letter symbols used should be defined where they first appear, in the illustrations or in the text, and arranged alphabetically in an Appendix.

6. Tables should be typed (an original ribbon copy and two duplicate copies) on one side of 8½-inch by 11-inch paper. Specific illustrations and explanation must be made in the text for each table.

7. Illustrations must be drawn in black ink on one side of 8½-inch by 11-inch paper. Because illustrations will be reproduced with a width of between 3-inches and 4½-inches, the lettering must be large enough to be legible at this width. Photographs should be submitted as glossy prints. Explanations and descriptions must be made within the text for each illustration.

8. The desirable average length of a paper is about 12,000 words and the absolute maximum is 18,000 words. As an approximation, each full page of typed text, table, or illustration is the equivalent of 300 words.

9. Technical papers intended for publication must be written in the third person.

10. The author should distinguish between a list of "Reading References" and a "Bibliography," which would encompass the subject of his paper.

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PIPELINE DIVISION

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PIPELINE LOCATION: AS-BUILT RECORDS[a]

Progress Report
Task Committee on Pipeline Location

SYNOPSIS

Regulatory agencies' requirements relative to as-built records are described for natural gas and common carrier pipelines. Federal Power Commission and Interstate Commerce Commission requirements are detailed; other agencies are listed and discussed in general. Methods of survey and mapping are given, as are the maintenance of as-built records to reflect changes after original construction.

INTRODUCTION

"As-Built Records" comprise the engineering phase of record-keeping as applied to natural gas transmission pipelines and common-carrier crude and products pipelines.

The purpose of making and maintaining as-built records stems from various factors: the mandatory requirements of the regulatory governmental agencies having jurisdiction over the pipeline companies; the requirements of other governmental agencies; and the requirements as set forth by the pipeline company itself. The regulatory agencies having jurisdiction over the pipeline companies are the Federal Power Commission (FPC) (over the natural gas transmission pipe lines) and the Interstate Commerce Commission (ICC) (over the common carrier pipe lines). Other governmental agencies not having

Note.—Discussion open until July 1, 1961. Separate discussions should be submitted for the individual papers in this symposium. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Pipeline Division, Proceedings of the American Society of Civil Engineers, Vol. 87, No. PL 1, February, 1961.

[a] This paper will form the basis for a chapter in a proposed ASCE Manual of Engineering Practice.

jurisdiction over the pipeline companies, but requiring as-built records, range from federal agencies to local-level agencies. As the regulatory governmental agencies control rates and tariffs it is essential that they require as-built records to substantiate construction cost, which is a major factor in the determination of the rates and tariffs allowed. Other federal and local-level agencies are primarily interested in as-built records to determine how the pipeline as constructed affects the various projects that fall under their jurisdictions.

REQUIREMENTS OF REGULATORY AGENCIES

Federal Power Commission.—The FPC prescribes that companies within its jurisdiction shall keep in their books of account full information as to any item entered in such books of account, and all other data supporting or substantiating these entries. To this effect the FPC has established the "Uniform System of Accounts Prescribed for Natural Gas Companies." This system stipulates the accountable items and breaks them into various categories by account numbers. The pipeline company may, for its own convenience, further subdivide the prescribed accounts, provided that the subdivisions do not impair the integrity of the accounts. In addition, the FPC requires that all changes in plant accounts, additions, removals, and retirements shall be recorded by means of a job-order or work-order system. It further specifies what records are to be retained, the period of retention, microfilming of, and destruction of such records as prescribed in the FPC's "Regulations to Govern the Preservation of Records of Public Utilities and Licenses."

The FPC does not require that as-built records made and maintained by the company, such as rechain surveys, inventories and completion drawings, be submitted to it. However, these records are supporting data for many of the items in the plant account books and they must be retained and made available to the FPC upon request. It is therefore necessary that these records be made and retained.

The FPC requires that the as-built records made and maintained by the company in connection with construction projects, wholly or partially completed, be retained until the record is superseded or for a period of 6 yr after the construction, or plant, as it is referred to, is retired. The FPC further stipulates that microfilm reproductions of such records are not acceptable in lieu of the original records.

Interstate Commerce Commission.—The ICC prescribes that companies within its jurisdiction shall keep in their books of account full information as to any item entered in such books of account, and all other data supporting or substantiating these entries. To this effect the ICC has established the "Uniform Systems of Account for Pipe Line Companies." This system stipulates the accountable items and breaks them into various categories by account numbers, as with the FPC. The pipeline company may further subdivide the prescribed accounts provided that the integrity of the original account is not impaired by the subdivision. In addition, the ICC requires that all changes in carrier property accounts, additions, removals, or retirements shall be recorded by a job-order or work-order system. It further specifies what records are to be retained, period of retention, microfilming of, or destructions of such records, as prescribed for in their "Regulations to Govern the Destruction of Records of Common Carrier Pipe Lines."

As-built records made and maintained by the engineering department, such as rechain surveys, inventories, and completion drawings are, of course, supporting data for book entries and have to be retained. Regarding these records the ICC has prescribed that certain maps and records be submitted to them for valuation purposes per the ICC's Valuation Orders No. 26 revised No. 27.

Valuation Order No. 26 Revised, "Instructions to Govern the P[illegible]ion of Maps, Charts, and Schedules by Common Carrier Pipelines," r[illegible]res that the carrier company submit two types of drawings to them.

Right-of-Way Maps.—These maps are, in effect, completion alinement sheets prepared from a rechain survey and shall show the following:

1. The route of the pipeline or pipelines.
2. The length of the pipeline as indicated by survey stations and mileposts.
3. The topography along the line and adjacent to it, such as roads, railroads, water courses, cities, towns, and any other data that will assist in locating and identifying the pipeline.
4. Boundary lines, state and county or other political subdivisions, property lines of various properties crossed.
5. The index for the appropriate valuation sections, as approved by the ICC.

Land and Structural Maps.—These maps are more or less similar to certified fee property plats as registered in land offices and shall show the following:

1. The location and extent of lands owned or used by the carrier company, where several adjoining tracts have been obtained to form one parcel of land, the boundary lines, dimensions, calls, etc., and the acreage of each separate tract.
2. Property lines and names of adjacent land owners, if known.
3. All important fixed improvements in general outline.
4. All connecting or branch pipelines within property with survey stations.
5. The index for the appropriate valuation section, as approved by the ICC.

The ICC requires that as-built records made and maintained by the company, such as rechain surveys, inventories, completion drawings, and valuation reports in connection with carrier property be retained for a period of 10 yr after such property has been removed or abandoned. The ICC further stipulates that microfilm reproductions of such records are not acceptable in lieu of the original records.

Other Governmental Agencies.—Governmental agencies other than the preceding regulatory commissions may require that as-built records be submitted to them. These agencies range from federal to local level and their record requirements, if any, will be varied. Most of these agencies are primarily concerned with the manner in which the pipeline will affect facilities that fall under their jurisdiction, and usually a permit drawing revised to a completion status will suffice their needs. Some of the various agencies that may require records are as follows:

United States Corp of Engineers
United States Boundary Commission
National and State Park Commissions
National and State Forestry Commissions

State Drainage Districts and Levee Boards
Municipality and Township Authorities

The as-built records made and maintained by individual companies, other than mandatory requirements, are optional, and the methods of keeping and delineating such records will vary. In any event, there are certain basic reasons for making and maintaining records:

1. They substantiate account book entries on construction and material cost of any pipeline construction project.
2. They provide the basis for design and estimates of future construction.
3. They reflect accurate location and detail of the pipeline and its appurtenances, which is necessary for the operation and maintenance of the pipeline.
4. They provide the basis for information shown on maps that are required by various company departments, such as system maps, exhibit maps, operating maps, annual report maps, and so on.
5. They are used by the ad valorem tax department to substantiate taxable pipeline footage in different political subdivisions.
6. They are useful in satisfying property owners' questions relative to the pipeline location across their respective properties.
7. They are used to supply information to private companies, corporations, and governmental agencies in cases where the pipeline location might have a direct bearing on an installation they propose or have under study.

METHODS

In making the as-built records on a pipeline there are certain factors to be considered, namely, the location of the pipeline, the physical makeup of the pipeline, and the as-built plans of the pipeline. The location of the pipeline is finalized by a field survey, the physical makeup by a field inventory, and the as-built plans by compilation and delineation of the field survey and inventory information. An important function in the establishment of as-built records is performed by the construction engineer, as discussed in another of these committee's reports.[1] The methods of obtaining, compiling, and delineating the record information may vary among different companies, but there are basic fundamentals that must be adhered to, as will be examined.

Survey.—During the course of pipeline construction, conditions arise that will necessitate the relocation of the pipeline or its appurtenances from the location as specified on the construction plans. Property owners may desire that the line location across their properties be changed or field engineers may decide to relocate the line due to terrain and soil-condition difficulties or to avoid crossing certain properties. It is because of such changes that a rechain survey has to be made. The rechain survey, also referred to as a completion survey, as-built survey, or final survey, has one primary purpose: to record any deviations or location changes from the original construction plans, so that final maps of the pipelines as constructed may be prepared. The rechain survey should entail the following:

1. A rechain of the relocated portions of the pipeline along the ground or the exposed pipe, either being acceptable, should be made.

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[1] "Pipeline Location: Duties of the Engineer on Construction," (Proceedings Paper 2739).

2. Deflection angles, property lines, terrain, clearing and ditching conditions along relocated portions of the line are to be recorded.

3. The beginning and ending survey stations, on the rechain of relocated portions of the pipeline, should be referenced to existing construction survey stations at these points.

4. The field notes of the rechain survey should be plainly noted as such, in order to avoid confusion with preliminary survey relocation notes.

5. The location of all pipeline appurtenances, whether falling in a relocated portion of the pipeline or not, should be verified.

6. When complete, the rechain-survey notes should be forwarded to the office where they are incorporated with unaffected preliminary-survey notes. From this a new set of office survey notes converted to continuous stationing is made, these being the equivalent of a complete rechain survey of the pipeline.

Inventory.—As stated previously, conditions arise that necessitate relocating a pipeline from the original plan; this also holds true for the materials that are used on the pipeline. Shortages caused by strikes or other conditions, shipping delays, or last-minute changes in plans may call for substitution of material in place of what was specified in the original plans. The primary purpose of the field inventory is to get a count of all material installed on the pipeline, regardless of whether it was changed in the field as previously noted, or installed according to the construction plans. The field inventory should entail the following:

1. A physical count, description, and location by survey station of the component parts of the pipeline as follows:

(a) Line pipe - The size, wall thickness, type manufacturer, and lineal footage based on the beginning and ending survey stations of the various pipe installed.

(b) Main line valve, tape, scraper installation, etc. - The size, wall thickness, type, manufacturer, and lineal footage of pipe; size, type, pressure rating, manufacturer, and serial number, if any, of the valves installed; the size, type, wall thickness, and manufacturer of the fittings installed; the size, type, manufacturer, and serial number of valve operators installed: and size. length, and wall thickness of fabrications installed.

(c) River weights and anchors - The size by weight, type, manufacturer, and location and spacing by survey station, of the weights installed.

(d) Weight coating - The thickness, weight and lineal footage by survey station, and whether yard coated or field coated.

(e) Casing - The size, wall thickness, type, manufacturer and lineal footage of casing and vent pipe installed; the size, type, manufacturer, and number of casing insulators and end seals; and the location by survey station and description of facility cased.

(f) Protective coating - The amount and manufacturer of primer, enamel, and wrapping used; the type of coating, usually specified by the pipeline company as to the number of enamel coats, and wraps used; and the lineal footage based on the beginning and ending stations of the various types installed.

(g) Electrolysis test and protection sites - The kind of test site, usually specified by the pipeline company, as to foreign line crossing test sites, calibrated test sites, insulated test sites, etc.; the number, size, and lineal footage of wire installed; the type, manufacturer, and number of receptacles

installed; the type and size of post used and location of the post by survey station. The kind of protective site, rectifier, or anode bed or combination of; the type, rating, and manufacturer of the rectifier; the number and type of anodes used and the spacing of them; the size, type, and lineal footage of wire installed; the size, type, and amount of wire, poles and hardware used to furnish power to the rectifier; and location by survey station of the rectifier or anode bed.

(h) Road and aerial pipeline markers - The size and type of post installed, the number of the aerial marker, the milepost of the road marker, and location by survey station.

2. The inventory should be presented by means of sketches of the completed installations, or by as-built marked construction prints of the installations. The sketches or as-built marked prints should be clear and concise, with complete material description and dimensioning for detailing and layout delineation. They should also reflect the date of the inventory, the name of the person making the inventory, the job order or construction section if assigned, description of the appurtenance inventoried, and the appropriate account number, as set up by the regulatory commissions for the use of the plan account section.

3. Upon completion of the field inventory the sketches or as-built marked construction prints are forwarded to the office for processing. Survey stationing is changed to conform to that of the rechain survey, tabulated inventory lists are prepared, and the necessary information is transferred to the final plans.

Mapping.—Upon receipt of the rechain survey notes and the field inventory sketches, the final drawings incorporating all construction changes are prepared. These drawings, referred to as completion, as-built, final or rechain alinements, have one basic purpose, that is, to present a picture of the pipeline and its appurtenances as finally constructed. Some of the considerations to be taken into account in the preparation of the final drawings are as follows:

1. There are different types of rechain alinement drawings presently in use, the most common types being the conventional type of sheet upon which the map background and topography are drawn by a draftsman, usually using pencil or ink on tracing paper or cloth, and the aerial alinement-sheet upon which a mosaic background is produced, through photographic means, to a matte-finish medium, which is suitable for drawing. Another method, although not as commonly used, is the use of a transparent matte-finish film overlayed on aerial mosiac sheets, all information being shown on the overlay sheet. Of these methods, the use of the aerial alinement sheet reproduced from aerial photographs is becoming increasingly popular for several reasons: (1) Drafting time is cut down, since all topography is on mosaic; (2) Topography on the mosaic is more accurate and complete; (3) Advancements in reproduction equipment, materials and methods, have refined the quality of final prints obtained; and (4) Photographic printing medium used is dimensionally stable and durable.

Inasmuch as the rechain alinements are a permanent record, subject to frequent printing and revision, it would be advisable to use a durable type, medium, either ink on tracing cloth or ink on photographic paper, dependent on the type of sheet used.

2. The rechain alinement drawings should show the following:

(a) A topography strip, with the pipeline centered on it, the strip being a minimum of 1 mile in width.

(b) All topographic features crossed by the pipeline should be noted by the pipeline rechain survey station.

(c) All geographic and political boundary lines crossed by the pipeline should be noted by the pipeline rechain survey station.

(d) All deflection angles should be noted by the pipeline rechain survey station.

(e) All properties crossed by the pipeline are to be noted as to the property owner and right of way tract number assigned. Property lines should be noted by the pipeline rechain survey station.

(f) Electrolysis test and protective sites should be noted by the pipeline rechain survey station and designated by symbol as to type of site.

(g) Main line valves, taps, scraper traps, etc., should be noted by the pipeline rechain survey station.

(h) Piping details of main line valves, taps, scraper traps, etc., should be drawn on supplementary sheets and included as part of the rechain drawings.

(i) Plans and profiles of major water crossings should be drawn at an enlarged scale on supplementary sheets, and reflect river weight coating information, bank protection measures if used, as well as water surface and top of pipe and stream bed elevations. If the pipeline is carrying liquids, a profile along the entire length of the line should be shown.

(j) The rechain stationing should start at the origin of the pipeline and continue with the flow of the line to the terminus. Mileposts should be noted at 1-mile intervals along the pipeline.

(k) A piping band with the line shown in schematic form should be included on the sheets, and pertinent information as to line pipe, casing pipe, protective coating, weights, etc., should be included.

3. To arrive at rechain alinements a complete new set of drawings can be made or the preliminary alinement sheets can be converted to a rechain status. Of the two, the conversion of the preliminary alinement sheets is the most economical, unless relocations and changes in plan are of such volume and extent to make it impractical; this, however, is seldom the case. To accomplish the conversion of sheets with the minimum amount of labor, the preliminary sheets should allow two strips or alinement bands, one for the preliminary survey stationing and one for the rechain stationing, these being located above or below the topographic strip. The preliminary stationing is noted on the preliminary alinement band and the rechain stationing is noted on the preliminary alinement band and the rechain alinement band, thus eliminating erasure of all preliminary stationing.

4. Upon completion of the rechain alinements, the necessary prints are made and distributed to the various departments and field offices as required for maintenance and operational use.

MAINTENANCE

The initial phase of compiling as-built records on a pipeline project is by no means the final phase. In order for the as-built records to fulfill requirements, mandatory or otherwise, the records, particularly the rechain draw-

ings, should reflect the pipe line in a current status. Obsolete or out-of-date drawings can cause considerable confusion and sometimes costly mistakes. Invariably after a pipeline has been in operation over a period of time, changes will occur, valves may be added, the line may be relocated, casings may be added, or line pipe may be replaced. These changes have to be incorporated with the existing records and reflected on the rechain drawings. The same factors that apply for a new installation—rechain survey, field inventory, and rechain drawings—also apply to any changes made after the line is in operation. If the line has been relocated, a rechain survey of the relocated portion is necessary, likewise a field inventory of material removed and installed is necessary, and the extent of the relocation is delineated on the rechain sheets and noted by revision on them.

CONCLUSIONS

Records made and maintained by companies are, in effect, a history of transactions or projects engaged in by the company. The records are an invaluable source of information as to what transpired methods used, and results obtained. They are frequently used as a criterion or basis for future planning by company management. Inasmuch as as-built records made and maintained by company engineering departments are an integral part of the company's record program, both for company needs and mandatory regulatory commission requirements, it is essential that every effort be directed to insure concise and current records. Inadequate or poorly prepared records are not justified, nor will they fulfill the requirements of the company or regulatory commissions.

This report is respectfully submitted by the Task Committee on Pipeline Location, Committee on Pipeline Location of the Pipeline Division.

R. H. Dodds
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Journal of the
PIPELINE DIVISION
Proceedings of the American Society of Civil Engineers

PIPELINE LOCATION: ENGINEERING SERVICE AGREEMENT[a]

Progress Report
Task Committee on Pipeline Location

SYNOPSIS

A model agreement covering most types of engineering-survey services that a pipeline company might expect to obtain from outside organizations is presented. Representative Section headings: Location of Route; Scope of Project; (Items) Furnished by Engineer; (Items) Furnished by Company; Location Alinement; Inventory; Compensation; and Insurance Requirements indicate the material covered.

INTRODUCTION

As a part of its assignment to prepare material for publication on practices in pipeline location, this committee presents the accompanying model engineering service agreement for surveying and mapping services. It is deemed that pipeline companies engaging outside engineers for such services will be able to adapt this model to their specific requirements in many cases, and that the model is consistent with the requirements of ethical practice.

ENGINEERING SERVICE AGREEMENT

Engineering Services Associated, hereinafter referred to as the "Engineer," hereby agrees to furnish to Pipe Line, Inc., hereinafter referred to as the

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[a] This paper will form the basis for an Appendix item in a proposed ASCE Manual of Engineering Practice.

"Company," engineering services of surveying and mapping as specified below for approximately _________ miles of __________ (type) pipeline between __________ (location) and __________ (location), all in accordance with recognized engineering practice and in cooperation with the Company's authorized representatives.

I. LOCATION OF PROPOSED ROUTE

A map marked "EXHIBIT A" and transmitted in connection herewith and made a part hereof shows the tentative route of the pipeline. The starting point and terminus are defined as to Section, Township, Range, County and State. (or in compliance with another suitable cadastral definition)

II. SCOPE OF PROJECT

Scope of the work under this Agreement is to survey a pipeline route, obtaining sufficient engineering data for the preparation of maps and for the acquisition of right of way, for the purpose of constructing and operating a specified ________ -in. diameter pipeline.

III. STARTING DATE AND DAILY PROGRESS

A. Engineer shall commence work at ____________ (location) on or about __________ (day), __________ (month), ________ (year), and shall continue with due diligence until all work is completed in accordance with the job description and general specifications contained hereunder.

B. It will be the responsibility of Company's authorized representative to determine whether the weather is too inclement for survey work. Prescribed forms for daily work sheets will be approved by Company representative, hereinafter called "Field Engineer," as to time and progress of the project. Payment will be made for the progress shown on invoices submitted in triplicate by Engineer at the close of each calendar month. Upon the approval of such invoices by Company, payment will be made promptly for the amount shown thereon.

IV. RIGHT OF WAY - CONTACT, PERMITTING AND DAMAGES

All rights to enter upon private, public domain, or state lands will be secured by Company prior to the entry by the contract survey party. Any questions or disputes arising as to Right of Way payment or damages shall be referred to the Field Engineer for the proper handling by the Company's Right of Way agent.

V. MATERIAL AND EQUIPMENT FURNISHED BY ENGINEER

A. Engineer shall furnish at his own expense all transportation for his survey parties necessary for the proper performance of the work.

B. Engineer shall furnish all surveying equipment including but not limited to transits, tripods, levels, steel taps, chaining pins, level rods, range poles,

and axes. All surveying instruments shall be kept in proper adjustment at all times.

C. Engineer shall furnish all expendable supplies such as survey stakes (1 in.-by-2 in.-by-12 in.), lath (4-ft-long.), flagging (orange preferred), crayon, and other supplies deemed necessary by the Field Engineer to insure a well-marked survey.

D. Engineer shall furnish special equipment as follows:

1. ______________________________

2. ______________________________ (etc.)

E. Engineer shall furnish other special equipment upon written approval by the Company.

VI. MATERIAL FURNISHED BY COMPANY

A. Company will furnish all engineers' field books (transit and level), route maps (1/2 in. = 1 mile), ownership maps (County or area), Township plats from the U. S. General Land Office (USGLO), quadrangle sheets from the U. S. Geological Survey (USGS).

B. Company will furnish other forms that Company may deem necessary to expedite the survey, and for the keeping of appropriate records.

VII. CODE OF ETHICS

A. All operations shall be conducted in a prudent manner, and reasonable precautions shall be taken to avoid any damage, other than normal wear and tear, to gates, bridges, roads, cattle guards, fences, and stock watering facilities.

B. No firearms of any description shall be permitted to be carried on the right of way by any member of a survey party or in any car transporting members of a survey party.

C. Engineer shall make every reasonable effort to avoid antagonizing land-owners and tenants, and shall endeavor to preserve existing good relations between them and Company. In the event of any damage to crops, fences, and other property through negligence on the part of Engineer, Company will have the right to make settlement and deduct the amount thereof from money due Engineer under this contract.

VIII. LOCATION ALINEMENT

A. General.—The surveyed line shall follow insofar as may be practicable the projected line shown on photographs, topographic sheets, and other maps furnished by Company for survey purposes. No material departure from this projected line shall be made without the Company's consent.

B. Survey Methods, Procedure, and Notes.

1. The transit line shall be staked continuously on horizontal chaining at 100 ft intervals and the deflection angles turned to read to the nearest minute and recorded at all angle points. All P.I.'s, P.O.T.'s and fences shall be hubbed, guarded, flagged, and referenced 100 ft Rt. and Lt.

2. The true bearing may be obtained by solar observations, Polaris observations, or by the use of U. S. Coast and Geodetic Survey (USC & GS) and USGS azimuth points. The magnetic declination shall be set off on the transit so that the needle readings on the compass circle may be read directly from true north. The readings shall be recorded in the transit notes under column headed "Magnetic Course" as a check on the calculated course.

3. Field notes shall be recorded in a form approved by the Field Engineer; see field note specimens attached hereto ("EXHIBIT B.")

(a) All notes and sketches shall be neatly and legibly recorded in the field at the time the work is performed.

(b) Field notes shall not be transcribed or erased. Corrections shall be made by drawing a line through the deleted portion, which shall be marked "Void" with a reference to the page number of the corrected notes, where appropriate.

(c) The survey line shall not pass within 300 ft of a structure built for human occupancy, where applicable; provided, however, that in those states having laws, rules or regulations establishing greater distances by which such survey lines shall clear such a structure, such greater distances shall prevail.

(d) Highways, railroads, and other prominent structures located within 500 ft of the survey line shall be described and shown by stationing with estimated right-angle distances.

(e) The survey line shall be tied to the nearest section corner and, to the extent that they can be readily identified, the nearest quarter section corner, property corner, and property line. An intersection shall be made on the Township, Range line, and section line with engineering station, angle of intersection, distance to section corner, and the true identity of corner found with a complete description of all markings.

(f) The survey notes shall reflect the engineering station with appropriate sketches, and they shall include the following:

(1) Centerline, right-of-way lines, fences and similar features on all highways, railroads, county roads, city streets, irrigation ditches, canals, and other comparable features.

(2) Utility lines, specifying type, size and whether buried or overhead, with approximate overhead clearance.

(3) Topographic features such as top banks, toe of slopes, water lines, flood plains, bluff lines, arroyos, swamp or marsh lands.

(4) Culture and other features such as timber, crop cultivation, pastures, wasteland, and surface rock.

(5) A maximum deflection angle of 30° shall be maintained where practicable. Larger deflection angles shall be chorded with no less than 40 linear ft between side bends.

C. Highway, Railroad Crossings.—All highway and railroad crossings shall be profiled to show sufficient data to enable the drawing of crossing permit plats. Pertinent information shall consist of name or other designation of highway or railroad, angle of intersection, profile with corresponding datum to a point 300 ft beyond right of way lines, ties to engineering stations or labeled structures, and type of pavement. Appropriate bench marks shall be established in secure locations. Survey shall, where practicable, be tangent from a point a minimum distance of 300 ft prior to and beyond right of way lines; the minimum angle of intersection with the center line shall be 30°.

Each and every break in terrain shall be plussed, shots taken, proper identification noted and recorded.

D. River Crossings.—River crossings shall be surveyed and profiled to obtain sufficient data to make studies as to best possible crossing method. Secure name of river, angle of survey-line intersection with banks and channel, channel flow direction, high, low, and normal water lines, nature of soil, a cross section a minimum of 300 ft upstream and 300 ft downstream, and perpendicular to banks. All river crossings shall be at 90° to river channel. Appropriate bench marks shall be established in secure locations.

E. Mining Claims.—Where the survey is traversing mineralized area, it will be necessary to ascertain the boundaries and position of each individual mining claim with appropriate intersecting engineering stations on each side line or end line. Lode claim and placer claim forms will be furnished by the Company, to facilitate the duplication of the actual existing claim notices as to factual information.

F. Profile Levels.—Engineer shall, when specifically requested in writing, make a continuous profile concurrently with the slack-chain remeasurement, a level survey along the side of the open or backfilled ditch with coinciding engineer station, equated periodically, and intermediate bench marks shall be established in secure locations. A circuit of check levels shall be run periodically to the nearest USC & GS bench marks.

G. Datum and Bench Marks.—The datum to be used shall be the standard basic sea-level datum. Company will furnish Engineer with a list of USC & GS bench marks with established elevations in the area traversed by the pipeline route.

IX. INVENTORY

A. General.

1. The constructed pipeline shall be remeasured for inventory. The starting point shall coincide with the original survey line. The slack chain measurement shall be carried along the edge of the open ditch as closely as possible so that the accurate length of pipe may be obtained.

2. Slack chain measurement shall be continuous with use of chaining pins and following the profile of the ground. The slack chain shall be equated to the original survey at all P.I.'s, P.O.T.'s, fences, and other significant stations, to determine that there are no major discrepancies between survey measurements and slack chain. Distances shall be measured to a reference point at all P.I.'s, P.O.T.'s, and fences to establish the position of the pipe in relationship to the original survey line.

3. Additional data required from Engineer with respect to engineering stations are as follows:

(a) Engineering stations at which constructor began and ended ditching.

(b) Engineering station at which constructor began and ended various types of coating and wrapping.

(c) Engineering station at which constructor began and ended various types and wall thicknesses of pipe.

(d) Engineering station for beginning and ending of various types of ditch (rock-shot, rock-ripped or machine-ditched) and depth of ditch.

(e) Engineering station at block valves, pipe junctions, mile posts, beginning and ending of all casings.

(f) Centerline, right of way lines and fences on all highways, railroads, roads, and streets.

(g) Utility lines described as to owner, type size, and whether buried or overhead.

(h) Topographic features such as top of banks, toe of slope, water line, flood plain, bluff line, and arroyos.

(i) Culture and other features such as timber, crop cultivation, pasture, wasteland, and surface rock.

X. COMPENSATION

The Engineer shall perform all duties incidental to this agreement, in accordance with the fees specified below. All per diem items as well as mileage allowances are included in these rate schedules.

A. Special Work or Per Diem Prices.—Survey Party and other personnel for special work requested by the Company, including moving party to various locations necessitated by rerouting or refinement of work; moving time to be based on hourly or daily rate schedule for survey party or other personnel, which shall include mileage allowance, subsistence allowance. Company will have the privilege of electing to use individual contract personnel at the applicable rates given below, under Item B, or party rates given under Item C, whichever is to the advantage of Company. The following rate shall be applicable to an 8-hr day or 40-hr week operating within a radius of 100 miles of their permanent headquarters. Rate Schedule applicable to work beyond operating limits shall be included below in Items D and E.

		Hourly Rate	Daily Rate
B.			
	1. Party Chief		
	2. Instrument Man		
	3. Chairmen		
	4. Laborers		
	5. Vehicle, all expenses paid over 100 miles per day		
C.	1. Three man party		
	2. Four man party		
	3. Five man party		
D.	1. Party Chief		
	2. Instrument Man		
	3. Chairmen		
	4. Laborers		
	5. Vehicle, all expenses paid over 100 miles per day		
E.	1. Three man party		
	2. Four man party		
	3. Five man party		

F. Whenever work in excess of 8 hr in one day is deemed necessary by the Field Engineer and so authorized, additional compensation in the amount of _____% of the basic hourly rate will be made by the Company.

G. For special equipment listed in Paragraph V-D above, the following fees will be paid:

1. (Item) ______________________________ $ __________

2. (Item) ______________________________ $ __________ (etc.)

H. Other special equipment (see Paragraph V-E above) will be compensated in accordance with the terms of negotiations at the time written approval is given by the Company.

XI. INSURANCE REQUIREMENTS

Contractor shall carry and maintain throughout the performance of this project, the following insurance:

A. Workmen's Compensation and Employer's Liability Insurance statutory for the state or states in which work is to be performed.

B. Comprehensive General Public Liability insurance with limits of not less than __________ per person and __________ for accident and General Public Liability Property Damage with limits of not less than __________ per accident.

C. Comprehensive Automobile Liability insurance, including hired cars and non-ownership endorsements with limits of not less than __________ per person and __________ per accident and Automobile Property Damage insurance with limits of not less than __________ per accident.

Certificates of such insurance shall be filed with Company and shall be subject to its approval for adequacy of protection.

XII. LITIGATION

Nothing in this Agreement is to be construed to obligate the Engineer to prepare for or appear in litigation in behalf of the Company, except in consideration of additional compensation.

XII. TERMINATION

If, during the progress of the work, it should become necessary for the Company to suspend this work or abandon it, the services of the Engineer may be terminated upon receipt of ______ (_____) days' written notice. In the event of such termination, the Engineer shall be paid the proportion of the amount due him under Article X at the termination date, including commitments that cannot be terminated and paid at the time of such termination.

This agreement made the _____ day of _________ in the Year ______ A.D., by and between ______________________________, hereinabove called "Engineer," and ____, hereinabove called "Company."

______________________________ ______________________________

By ______________________________ By ______________________________

Engineer Company

This report is respectfully submitted by the Task Committee on Pipeline Location, Committee on Pipeline Location of the Pipeline Division.

R. H. Dodds
J. C. Faulkner
J. F. Schaffer
E. H. Schmidt
M. O. Schmidt
E. O. Scott, Chairman

Journal of the

PIPELINE DIVISION

Proceedings of the American Society of Civil Engineers

PIPELINE LOCATION: DUTIES OF THE ENGINEER ON CONSTRUCTION[a]

Progress Report
Task Committee on Pipeline Location

SYNOPSIS

Functions of the engineer on construction are described as follows: relocations due to right of way and other requirements; restaking and referencing for construction and as-built records; supervision, progress control, and survey control of major crossings and site work; quantity measurements.

INTRODUCTION

It is desirable that the field engineer who supervises the reconnaissance and location survey for a pipeline be assigned as the construction engineer on a section of the pipeline, serving in that capacity until the line is completed and accepted by the company. Thus, the construction can benefit from the engineer's thorough familiarity with the problems involved. The engineer's duties on the construction phase of a pipeline are varied. The extent of his responsibility and functions depends on management's policies, the location of the project, and the type of line being constructed.

The purpose of this paper is to outline the most probable functions that the engineer will perform during the different phases of construction. The

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[a] This paper will form the basis for a chapter in a proposed ASCE Manual of Engineering Practice.

paper is divided into parts corresponding more or less with the construction phases.

RIGHT-OF-WAY

The engineer on construction should be in close contact with the right-of-way representative or supervisor on his section at all times. At the beginning of construction, portions of the right-of-way may not have been acquired or finalized, and special provisions for construction may have to be guaranteed in order to secure easement. Sometimes these special requirements or provisions may make it necessary to consider relocating portions of the line. When such conditions arise, the engineer and right-of-way man should study and evaluate all possibilities and agree on the most feasible location with all factors considered and evaluated.

The engineer and right-of-way man, being informed on the matter of special provisions, should communicate this information to other interested construction personnel. The engineer may elect to indicate on the ground areas where special provisions are imposed (by special stakes or flags) or to show on working prints where construction will have to deviate from standard practice.

Another matter that calls for close cooperation between the engineer and the right-of-way man is the securing of permits from federal, state, and local agencies having jurisdiction over highway crossings, drainage districts, river crossings, federal and state lands, monuments, parks, forests, game preserves, and other properties. They should also work closely on securing permits from privately-owned entities that may require permits, such as railroads, power companies, lumber companies, and others. The two should also establish a means of checking the status and requirements of all permits so others concerned can be advised and kept informed. In many instances permits require some engineering and checks at the location of the crossing or site when the pipeline is being installed, so the engineer should be available to assist when called upon by construction personnel.

During the final phase of construction the engineer is called upon to check on questionable damage claims and furnish to the right-of-way department any engineering data or maps they request to substantiate or discredit such claims.

RESTAKING AND REFERENCE STAKES

Stakes are often obliterated, broken, or destroyed before construction is started, especially when there is a lapse of time between the staking of the line and the beginning of construction. Many stakes become effaced or destroyed during the construction itself, unless the contractor preparing the right of way or stringing pipe takes special measures to preserve the stakes.

It is the responsibility of the construction engineer to see that sufficient stakes are in place at all times for the guidance of excavating machinery to prevent any damage or rupture of lines, especially if the line being constructed is adjacent to existing active lines. Also, any crossovers of owned lines, foreign lines, or any other underground facilities should be well staked and flagged.

A line under construction sometimes crosses properties on which the working space is limited by the right-of-way contract, by existing lines, or

by some other physical obstruction. This situation will require the engineer in charge to stake the limits of the working space so that no agreement will be violated and no property will be endangered or damaged. The working space should be staked and flagged in a way that will leave no doubt as to the boundaries of the limitations.

During the construction of a line and prior to the actual inventory, the engineer should know what information will be required on the rechain or inventory and make use of every opportunity to set reference stakes and to record the information on facilities or installations while they are visible or prior to being backfilled. Data include such items as drain tile, sewers, conduits, water lines, and foreign pipelines crossed by the pipeline under construction.[1] The engineer should be sure that sufficient station stakes are in at all times for reporting the progress of the different phases of construction.

In addition, reference stakes or ties should be made relative to such items as changes in pipe weight and kind, protective coating, casing installations, appurtenances, river weights and anchors, weight coating, and the limits of contractor's work. These data are required for the purpose of final settlements as to the amounts of standard ditch excavated, extra-depth ditch excavated, protective coating applied, and amount of pipe laid. The construction engineer should keep in mind at all times the necessity of establishing references and taking enough notes and measurements so that the "as-laid" or "as-built" records can be made complete and accurate.

CROSSINGS

On long and difficult highway, street, and railroad crossing, grades and alinements checks are usually necessary and require an engineer to be present at the time such crossings are installed.

On major stream crossings the responsibilities of the construction engineer are numerous. The engineer, usually working from a monumented base line, should set-up targets, markers, gauge boards, buoys, and any other guides needed to keep the excavating equipment on alinement and to establish the limits of the trench. At the time the trench is being dug the engineer is relied on to furnish progress data and to check the trench with respect to compliance with all requirements. It is also a common practice for the engineer to keep a daily log on a major stream crossing including such records as the stage of the river, hours equipment worked, weather, general progress, any unusual conditions, and any information that is practical to obtain as to the type of excavation encountered. On the laying of the pipeline across a major river, the construction engineer is expected to check and profile the line as it is placed in the trench to see that it conforms to specifications and meets the depth and other requirements of regulatory bodies. He should also be able to furnish all data for the as-built records and have all necessary points referenced and monumented.

On small stream crossings the profile of the line in place and the as-built information is essential.

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1 "Pipeline Location: As-Built Records," Proceedings Paper 2737.

The replacement and stabilization of river banks after the construction of a line quite often proves a problem, so the construction engineer may have to act as an adviser to other construction personnel on means and ways to obtain adequate bank protection.

MISCELLANEOUS DUTIES

The construction engineer may have to keep a record of different items such as the quantities of shot rock, ripper rock, extra-depth ditch, and bank protection.

The locations of block valves, meter stations, and taps are usually designated by the construction engineer after considering accessibility, terrain, and the availability of sites. The proper location for aerial markers and milepost markers are usually designated by the engineer.

RELATED CONSTRUCTION

The following are additional duties, related to station construction, that may be assigned to the construction engineer, depending on his work load and the magnitude of the project.

1. Station layouts, including the location and grades of buildings, drainage, machinery foundations, sanitary facilities, auxiliary pipelines, tanks, roads, parking areas, air strips, and other necessary features.
2. Layout and determination of the capacities of firewalls, and computation of the quantities of earthwork in these works.
3. Establishment of the location of scraper traps, manifolds, and other appurtenances.

SUMMARY

The duties and responsibilities of the construction engineer have been generalized, and in many cases they may be expanded or reduced depending on the project, management policies, and the availability of other personnel.

The duties also will vary with the type of line being constructed, whether it is gas, crude products, or L.P.G., or whether it is a trunk line, gathering line, or local distribution line.

This report is respectfully submitted by the Task Committee on Pipeline Location, Committee on Pipeline Location of the Pipeline Division.

R. H. Dodds
J. C. Faulkner
J. F. Schaffer
E. H. Schmidt
M. O. Schmidt
E. O. Scott, Chairman

Journal of the

PIPELINE DIVISION

Proceedings of the American Society of Civil Engineers

PIPELINE LOCATION: RECONNAISSANCE[a]

Progress Report
Task Committee on Pipeline Location

SYNOPSIS

Reconnaissance results in a report on which management bases its decision to construct a pipeline. Procedure described includes: assembly and analysis of available data, preparation of a strip map for field use in preliminary reconnaissance by air and ground; selection of general location; detailed ground reconnaissance; preparation of the report.

INTRODUCTION

Purpose and Scope of Reconnaissance.—Reconnaissance for pipeline location embraces the evaluation of possible routes to serve specified points, and the determination of the most economical route. The reconnaissance report, which includes estimates of project cost, enables management to decide whether or not to proceed with location surveys and construction.

The engineer who conducts the reconnaissance must be thoroughly experienced in pipeline costs under the many conditions that can be encountered in the field.

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[a] This paper will form the basis for a chapter in a proposed ASCE Manual of Engineering Practice.

Cost Factors.—Principal cost factors to be considered in this review of prospective locations are location-survey costs, construction costs (including materials), right-of-way costs and maintenance, and operation cost.

RECONNAISSANCE PROCEDURE

All of these factors enter into the reconnaissance engineer's consideration of each project detail as he carries out the logical steps of his assignment: (1) assembly of available data; (2) map analysis and preparation of strip maps for field use; (3) preliminary reconnaissance by air and ground; (4) preparation of reconnaissance maps, showing the general route selected after preliminary reconnaissance; (5) a detailed ground reconnaissance; and (6) prepration of the reconnaissance and cost report.

Available Data.—Existing maps and photographs are the principal items to be analyzed in the selection of possible routes for a pipeline.

United States Geological Survey, Dept. of Interior (USGS), topographic sheets, available for many areas in scales from 1/2 in. = 1 mile to 2 in. = 1 mile, are useful at this stage. Others are U.S. Army Map Service strategic maps (small scale), Civil Aeronautics Administration (CAA) flight maps, state or sectional highway maps, county highway maps, and specialized maps of various scales. The better topographic maps are good sources of much precise survey control data, distances, and elevations for hydraulic design.

Photographs may be those with which the newer topographic maps have been plotted; they may be U.S. Department of Agriculture Soil Conservation Service photos or they may be part of numerous collections taken for area-planning purposes, tax-map purposes or other purposes. It is particularly desirable to find photographs of potential river crossings, passes, and other terrain features that influence location importantly.

Probably the most complete source of information on available maps, photographs, and control data is:

Map Information Office
U.S. Geological Survey
Washington 25, D.C.

Appendix I cites some of the types of map information available from this office. Several states also maintain centralized map-information services.

Map Analysis.—A detailed office reconnaissance of the available planning maps and photographs to aerial or gound reconnaissance is important. They contain the necessary geological and physical information to enable the reconnaissance engineer to define closely satisfactory routes. They enable the selection of the most promising lines from sources of supply to gathering points and from gathering points to points of delivery. Major physical obstacles such as rugged terrain, heavily populated areas, and marsh lands can be eliminated prior to reconnaissance.

Strip maps of potential routes should be prepared to a scale such as 1 in. = 1000 ft, by techniques of enlargement or reduction from existing-map sources. The scale chosen should be large enough to provide space for notes and it should be small enough to permit unrolling without undue haste.

Preliminary Reconnaissance.—It is frequently advisable and economical to fly over the potential routes before beginning the ground reconnaissance. The strip maps are easily used as flight maps. A diary of the flight and findings is essential. Notes on maps or notebooks are invaluable. A tape recorder, field glasses, and camera are great assets.

Air reconnaissance is actually only a fast-moving, large scale, cursory examination. It is a planning aid, not a detailed examination. However, it is important to review the route from the air to eliminate major physical obstacles, and to select the most satisfactory general locations for compressor pumping station sites, river crossings, highway, and railroad crossings. These are critical points at which the lines should be fixed before ground reconnaissance is started. In the area the reconnaissance engineer should note and describe the type of terrain, crops and other ground cover, surface geology and man-made structures. He should circumscribe areas to be avoided, noting locations for additional study during ground reconnaissance. Back in the office he can modify the routes he originally selected before starting ground reconnaissance.

Information to be obtained during aerial reconnaissance includes: Terrain—whether flat, gently rolling, rolling, steeply rolling, heavy rolling, or broken and rough; culture—whether timber, field crops, pasture, orchards, truck gardens, nurseries, or other distinctive culture; surface geology—such features as eroded areas (wind or water), rock, dunes, general drainage, major streams, lakes, ponds, sink holes, swamps, marshes, muck beds, slide areas, cliffs, and muskeg; and man-made features—such as transmission lines, types and density of roads, railroads, pipelines, industrial areas, suburban areas, resort areas, parks, golf courses, landing strips, military installations, drainage canals, irrigation canals, reservoirs.

After flying, marked-up strip maps, notes, and tape-record transcription are analyzed and rough cost comparisons are run on the promising routes. A second flight may be desirable to review the promising routes and clear up questionable points.

Ground reconnaissance of promising routes can be made by automobile, except in critical and inaccessible locations, where the route should be checked on foot. Considering that this preliminary reconnaissance is made to select a route that can be photographed and not to pin-point the exact locations to be surveyed, this preliminary reconnaissance should proceed rapidly. However, every effort should be made to eliminate all costly obstacles to construction and operation.

Generally the following items should receive prime consideration during this preliminary reconnaissance.

River Crossings.—River crossings are costly to construct. If crossings are not properly located for permanence they can be serious sources of trouble during operation. Interruptions in service resulting from breaks at river crossings result in serious losses in operating revenues and repair costs. The ideal crossing has high, stable banks and a straight, stable channel. A rock bottom may be costly to excavate but may be the stabilizing factor that will hold the pipe under flood conditions.

If a federal or a state navigation or water control body has jurisdiction over the river at the point of crossing it will be necessary to obtain a license to cross. This body, which must be consulted prior to obtaining a permit, can also be a valuable source of information regarding the characteristics of flow and the stability of the banks and the channel. It will stipulate the depth at which the pipeline must be laid below the channel. Its hydrographic records will show the high water mark, the minimum elevation at which manifolds or gate valves should be located. The reconnaissance engineer should determine to his satisfaction whether a crossing should be laid with a single line, dual lines or on a bridge overhead. His study should consider the experience of operating pipelines in the area.

Rock and Rugged Terrain.—Extensive areas of rock of a hardness that will result in costly excavation and ditch padding or rock shield should be bypassed. Often rock is not visible from the surface because of a heavy soil overburden. However, it is often apparent in highway and railroad cuts or creek beds and steep slopes. It is usually wise to consult the geological agency of each state to obtain rock profiles or information regarding rock formation in the vicinity of the proposed line. Areas of rugged terrain generally contain some rock. However, even without rock, construction and operation of a pipeline through rugged terrain can be expensive. Rugged terrain is generally characterized by steep slopes and narrow, deep gullies, arroyos, or stream beds. Pipe laid in such terrain must contain numerous overbends and sag bends, which are not only costly to construct, but also affect the hydraulics of the lines. The ditch will wash on steep slopes and in rapid stream bottoms, requiring excessive maintenance. Rugged terrain should be by-passed or substantially eliminated, if this is possible without increasing the length of the line materially.

Areas of High Land Crop Values.—Real estate values are generally high in the vicinity of communities, therefore it is wise to locate the pipeline at a reasonable distance from existing developments. However, land values may be exorbitantly high where expensive high-yield crops are grown. To avoid such expensive right of way, the reconnaissance engineer should select locations to miss such plantings as orchards, garden crops, nursery stock, tobacco, rice, marketable timber, and so on.

Additional Items to Note.—In addition to the foregoing, during ground reconnaissance particular note should be made of the following: (1) Railroad and Highway crossing type and amount of casing required; (2) transmission line power data; (3) foreign pipeline and cable location; (4) rock, slide areas, swamps, marshes, muck beds, and height of water table; (5) accessibility to route for stringing and maintenance and from shipping points; (6) general types of soils that will be encountered; and (7) rainfall, average temperature, frost depth, snowfall, first and last killing frost, and so forth.

On this travel the reconnaissance engineer should be accompanied, when feasible, by a geologist, a construction or maintenance man, an estimating engineer, and a right-of-way man. Maps and notes prepared for the study should be taken along, as should such equipment as a tape, compass, altimeter, field glasses, camera, and tape recorder. Approximate measurements for estimating major construction qualities should be made as this reconnaissance proceeds.

Certain state and county information also should be obtained, including: (1) From highway departments—road crossing specifications; permit form; future expansion or highway program; (2) from the waterway agency—requirements for crossing of streams under state jurisdiction, etc.; (3) from the conservation agency—location and requirements for state forests, park areas, game refuges, etc.; (4) from the state land office—requirements for crossing state-owned lands; (5) from the state geological agency—geological maps, soil maps, drainage maps, bench mark data, etc.; (6) from the state university—agriculture atlas, soils, industry, climate, data, etc.; and (7) from the county or parish governments—maps, specifications, permits, zoned areas, plat books, and soil maps.

Major codes affecting pipeline location and design are treated elsewhere.[1]

Preparation of Reconnaissance Maps.—Upon completion of the preliminary air and ground reconnaissance by subsequent analysis, the engineer has probably pinned down the location of the line to be constructed to within a width of 1/2 mile. He is now in a position to prepare base maps to be used for aerial photography and subsequently surveying, mapping, and right of way work. He should revise the lines on the maps he has previously prepared so that they may be used for flight maps.

Photography should be procured at this stage, particularly if photographs are not available or if available photographs are not suitable from such standpoints as scale and up-to-dateness, because they will be used frequently in subsequent engineering steps.

Contact prints are used for stereoscopic interpretation of terrain in the office prior to ground reconnaissance, in the field during the reconnaissance and throughout surveys. Thorough stereoscopic study is an invaluable aid to selecting the best location while maintaining the shortest lines. Ground reconnaissance augmented by stereoscopic photo interpretation will provide optimum results.

As an aid in photograph procurement, Appendix II (not included in the present paper) is an outline specification for aerial photography.

Other photographic aids, utilizing the basic photography, are continuous strip mosaics and mosiac sheets on transparencies. A convenient scale for both is 1 in. = 1000 ft. The former are convenient for field use where numerous single photos may become unmanageable. The latter can cover 5 miles of alinement per mosiac and can be used in conjunction with profiles to make "atlas sheets."

Detailed Ground Reconnaissance.—Detailed ground reconnaissance is similar in scope to the preliminary ground reconnaissance, requiring the same grouping of skills and type of data about the route. More detail is observed, but it is usually observed along a single narrow strip.

Upon completion of the detailed ground reconnaissance, the reconnaissance engineer should have selected the exact location to be surveyed. This will necessitate continually altering the route and delineating this route on the contact prints and maps with which he is working. It will require examination and re-examination of the altered routes as he proceeds.

He also will have made measurements and estimates of sufficient precision to yield preliminary quantities of earth excavation; rock excavation; river pipe; casing and vents; special protective coating; rip rap, various kinds; extra depth ditch; timber; weights and anchors; and tile troughs.

RECONNAISSANCE REPORT

Upon completion of the analysis of detailed ground reconnaissance, including computation and cost analysis of construction quantities, the report to management is prepared. Feed-in of non-construction cost factors such as right of way, maintenance and operation also is accomplished. (See Appendix III for a discussion of right-of-way factors.)

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[1] "Regulation of Pipeline Design and Construction," Progress Report, Proceedings, ASCE, Vol. 85, No. PL 2, May, 1959.

By means of the written report and attached exhibits including route maps or mosaics the report should accomplish the following:

1. Locate accurately the pipeline location that is the most economic route best suited for construction, operation, and maintenance.
2. Provide a complete preliminary inventory and estimate of the cost of materials, construction, surveying, mapping, and right-of-way services necessary to install the pipeline.
3. Provide the physical, topographic, and ownership maps necessary for the performance of the subsequent services required to build a pipeline.
4. Provide information as to the requirements for permits to construct the line across all federal, state, and municipally owned rights of way and lands.

This report is respectfully submitted by the Task Committee on Pipeline Location, Committee on Pipeline Location of the Pipeline Division.

R. H. Dodds
J. C. Faulkner
J. F. Schaffer
E. H. Schmidt
M. O. Schmidt
E. O. Scott, Chairman

APPENDIX.—MAPS AND INFORMATION AVAILABLE FOR PLANNING

FEDERAL AGENCIES

A. Aerial Photography

1. Status Map of Aerial Mosaics—Compiled by the Map Information office.. This map shows all areas for which aerial mosaics are known to have been compiled by or for federal, state, and commercial agencies.

2. Status Map of Aerial Photography—Compiled by the Map Information office. This map shows all areas known to have been photographed by or for federal, state, and commercial agencies.

B. Topographic Maps

1. Status Map of Topographic Mapping—Compiled by the Map Information office. This map shows coverage by topographic and planimetric quadrangle maps, published at various scales, ranging from 1:24000 to 1:25000.

2. Index Map of Topographic Sheets, by States—United States Department of the Interior, Geological Survey. These maps show quadrangle sizes, names, scales, and dates of survey. Quadrangle sheets covering areas in the states west of the Mississippi River may be ordered directly from the United States Geological Survey, Federal Center, Denver,

Colo. Maps for areas east of the Mississippi River should be ordered from the United States Geological Survey, Washington 25, D.C.

3. There are quadrangle sheets prepared by the Army Map Service, Corps of Engineers, United States Army, Washington, D.C. These maps may be obtained from the United States Geological Survey offices, above-named. They cover large areas and have greater contour intervals than the regular quadrangle maps; however, they may cover areas where other maps are not available.

C. Control Leveling Data

1. There is an index map for each state showing the lines of levels that traverse it. A list of bench marks, their elevations and descriptions, may be obtained in conjunction with any line of levels. These maps and the information on the bench marks may be acquired from The Director, Coast and Geodetic Survey, United States Department of Commerce, Washington 25, D.C.

2. Information is available on additional bench marks from the United States Geological Survey, Department of Interior, through the Superintendent of Documents, Washington 25, D.C.

D. Miscellaneous Maps and Information

1. There are many other maps and information avilable from the Superintendent of Documents, which may be helpful in the location and survey of a pipeline, some of which are listed below:

   a. Plane coordinate intersection tables by states.
   b. State maps compiled from official records of the United States Bureau of Land Management and other sources.
   c. Location of irrigated land by states.
   d. Reclamation activities (present and proposed).
   e. Map showing national parks, monuments and parkways, national historic sites, Indian reservations, national wild life refuges, and national forests.
   f. Transportation maps, showing highways, railroads, canals, air lanes, and dredged channels.
   g. Navigation and Flood Control Projects Map—Office of Chief Engineers, Washington, D.C.
   h. Township Maps of Original Land Survey—These maps are helpful in establishing land lines. They may also be used in checking ownership, making up survey sheets, and plotting survey notes. Director, Bureau of Land Management, United States Department of Interior, Washington, D.C.

2. Sectional Aeronautical Charts—These charts may be obtained from most local airports or from the Director, United States Coast and Geodetic Survey, Washington 25, D. C.

STATE MAPS

A. Many states have maps and information available which are helpful in locating a pipeline and other information to supplement observations made dur-

ing the reconnaissance survey. Some of the maps and information that may be obtainable are as follows:

1. Agriculture Atlas—Will have information on land use, land value, climatic conditions, rainfall, timber, soil, etc.
2. Consevation Property Map.
3. Drainage Map
4. Geological Map
5. Base Map
6. Soil Maps
7. Bench Marks
8. Bedrock surface Map
9. Oil and Gas Industry Maps
10. Base Map (Highways)
11. Bulletins on Soils
12. Maps and Brochures on Highway Expansion
13. Highway and Transportation Maps

COUNTY MAPS

A. The available maps in counties vary considerably; however, in many cases useful maps can be obtained including the following:

   1. Platbooks—these books usually are distributed by Farm Bureaus in the counties. The ownership is usually shown, as is the size of the tract. Though the ownership is not necessarily correct it gives the locating engineer some idea of congestion and the number of properties that will have to be crossed.
   2. County Highway System Maps
   3. Drainage and Levee Districts Maps

APPENDIX III.—RIGHT-OF-WAY CONSIDERATIONS OF RECONNAISSANCE WORK

Rights-of-way for pipeline can generally be classified as follows:

1. Rights of way on private lands owned by individuals.
2. Rights of way on private lands owned by corporations.
3. Rights of way on municipal, state and federal lands.
4. Permits to cross municipal, state and federal lands, forests, parks, highways, roads, streams, canals, and drainage ditches.

5. Permits to cross rights of way of railroads, power companies, and pipeline companies.

In reconnaissance, ownership maps should be obtained and the proposed route delineated thereon. The rights of way should be observed and ownership noted. Many owners should be contacted prior to completion of reconnaissance. Each of the these types of right-of-way should receive the attention of a reconnaissance engineer.

1. Rights of Way on Private Lands Owned by Individuals.—It is not the responsibility of a reconnaissance engineer to know land and crop values, but it is his responsibility to recognize when land and crops have value, and to consider the cost of obtaining, constructing on, and maintaining rights of way on these lands. The value of crops can be determined by consulting landowners and local farm agents. High-value crops and lands that are subject to subdivision or industrial usage should generally be avoided because of the potential cost.

Re-routings later are expensive; therefore, investigation of use and ownership is a responsibility of the reconnaissance engineer.

2. Rights of Way on Private Lands Owned by Corporations.—Ownership by corporations, revealed by investigation of ownerships, heralds the existence or potential establishment of plant sites or mining operations. Contacts with these owners during reconnaissance may provide information as to the industrial, mining, or agricultural potential of the area. Frequently, commercially-held surface deposits of gravel, sand, coal, and other minerals may make the cost of acquiring rights of way prohibitive over large areas. Ownership investigations also will reveal the existence of irrigation districts and drainage districts. Many of these are incorporated. Irrigation and drainage practices may impose construction restrictions that will make re-routing necessary.

3. Rights of Way on Municipal, State, and Federal Lands.—These rights of way usually are automatically obtainable upon application unless the lands are owned for purposes that prohibit pipelines. The lands departments of the respective jurisdictions should be contacted to determine possible existence of restrictions.

4. Permits to Cross Municipal, State, and Federal Lands, Forests, Parks, Highways, Roads, Streams, Canals, and Drainage Ditching.—These public agencies must be contacted during reconnaissance to determine the acceptability of pipeline crossings. Construction restrictions or proposed plans of expansion of facilities frequently necessitate routing to satisfy these agencies.

5. Permits to Cross Rights of Way of Railroads, Power Companies, Pipeline Companies.—These owners must be contacted to gain their acceptance of proposed locations since the construction of pipeline across their rights of way may interfere with the proper operation or expansion of their facilities.

Rights of way costs that must be considered during reconnaissance are (1) initial cost of rights of way or permits; (2) cost of subsequent re-routing to satisfy construction restrictions that may be imposed to preclude interference with the use of lands; (3) cost of pipeline maintenance, including damages resulting from entry for maintenance; and (4) cost of additional pipeline necessary to by-pass rights of way.

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RATIONAL DESIGN FOR PIPELINES ACROSS INUNDATED AREAS

Progress Report on Task Committee on Floatation Studies
Committee on Pipeline Installations

SYNOPSIS

Causes of pipeline flotation, reasons for weighting, weighting criteria, and methods of pipeline weighting are reviewed; a survey of current practices in the pipeline industry for anchoring pipelines is presented; methods for more efficient and economical pipeline anchoring are suggested; and research to establish a technical procedure for the design of pipeline anchoring is recommended.

INTRODUCTION

A pipeline flotation committee was organized under the Pipeline Division of the American Society of Civil Engineers (ASCE) in May, 1959. The purpose of the committee was threefold: (1) to study the problems in conjunction with large diameter pipelines when placed in flooded areas; (2) to promote such research as necessary to put design of pipeline anchorage on a technical basis; and (3) to report its findings and recommendations to industry through facilities of the ASCE. Regular meetings of the committee are held in Houston, Texas.

An important initial action of the Task Committee was to prepare and send out questionnaires to survey methods for weighting pipelines in waterflooded areas. The questionnaire was sent to pipeline companies, consultants, and contractors working in the pipeline industry. A chief result of this questionnaire was to point up how pipeline people differ regarding weight required to

Note.—Discussion open until July 1, 1961. Separate discussions should be submitted for the individual papers in this symposium. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Pipeline Division, Proceedings of the American Society of Civil Engineers, Vol. 87, No. PL 1, February, 1961.

resist buoyancy in water-covered areas. A tabulation of the replies to this survey is included in this report.

The wide variation in replies to the questionnaire is indicative of the rule of thumb methods used to specify weighting and anchoring criteria. Results of the questionnaire show a need to bring the talent of the profession to bear on the problem and to establish technical methods for determining optimum pipeline weighting. Answers to this problem should come from a study of what the pipeline industry is doing, results with these methods, and appropriate and carefully selected research to bring solutions to unknown quantities in the pipeline stability problems.

The Task Committee is interested in initiating research covering the buoyancy of pipelines. A chief benefit of the committee's work thus far is to find the things that pipeline designers have in common and to sift out the problems that remain unanswered. Questions finally worthy of research must be specific unknowns and should have broad application and usefulness to pipeline problems. This report is written as an interim report to summarize the committee's progress to date and to determine the next phase of committee endeavor.

FACTORS CONTRIBUTING TO THE DESIGN OF PIPELINES TO RESIST BUOYANCY ACROSS INUNDATED AREAS

Many factors contribute to the stability of pipelines across inundated areas. The type of water bottom or flooded area is of utmost importance. It is reasonable to expect stability requirements for major rivers and for offshore pipelines to be more severe than those for quiet lakes or across marshes. Other cases are instances of construction of reservoirs or artificial lakes over existing pipelines. Some consideration should be given to the effect of flooding over the existing line even in these cases.

Pipeline weighting was developed to make river crossings with small crude oil or petroleum products lines. It came into paramount importance when construction of large diameter gas pipelines began. Early weighting was used to prevent a "swing" in a line across rivers and to make the pipe current resistant. Floating in water was no problem for oil and water lines. Today's large diameter gas lines constructed from high strength steels are thin wall and of such light weight that the bulk density of the line is often half or less than that of water. Using high strength steels, buoyancy in water is a problem even with fairly small gas lines.

Pipeline weighting is most critical in major river crossings and in offshore pipeline installations. Stability and security of the pipeline is largely dependent on weighting in these instances. The aim is to get the weighting that corresponds with the hazards to which the line may be exposed.

In marsh and swamp installations, the amount of anchorage depends on the method of laying and whether or not the line is to be backfilled.

In occasionally inundated areas such as river bottoms, flood plains, artificial water bottoms, and other low-lying areas, important economic gains can be made in the study of pipeline anchorage. Condition of occasional flooding in which the pipe might be laid in a dry season offers an opportunity for engineers to use anchorage qualities of natural materials more efficiently. Here is a situation to be decided by engineering judgment and a safe, economical design of pipeline anchorage will depend on correct appraisal of the factors involved.

Pipelines, in 1960, transport a multitude of products ranging from natural gas and oil products to liquefied sulphur and pulverized coal. Products in the pipeline are an important factor in evaluating weighting requirements for long-term pipeline operations.

Pipe size has influence on pipeline anchorage because anchoring becomes more critical with an increase in the size of the pipe. Table 1 shows how buoyancy is a function of diameter for gas pipelines. In smaller sizes, schedule 40 pipe is used. For pipes larger than 10 in. a wall thickness of 0.375 in. is arbitrarily assumed because so many different thicknesses are possible. Pipe weights should be reasonable for lines of these various sizes.

As can be seen from the table, gas pipelines in the larger diameters must be weighted very heavily to resist floating. Together with buoyancy, there are other water forces that must be resisted. Most common of these are current

TABLE 1.—RELATION OF BULK SPECIFIC GRAVITY OF PIPE TO DIAMETER

Diameter, in inches (1)	O. D., in inches (2)	Wall thickness, in inches (3)	Weight in lb per feet (4)	Volume in cu ft per foot (5)	Density in lb per cu ft (6)	Specific Gravity[a] (7)
2	2.375	0.218	5.02	0.0307	163	2.61
3	3.5	0.216	7.57	0.0668	113.3	1.81
4	4.5	0.237	10.79	0.110	98.1	1.57
6	6.625	0.280	18.97	0.239	79.4	1.27
8	8.625	0.322	28.55	0.406	70.3	1.13
10	10.75	0.365	40.58	0.630	64.3	1.03
12	12.75	0.375	49.6	0.887	55.9	.894
14	14	0.375	55	1.07	51.4	.822
16	16	0.375	63	1.40	45	.720
18	18	0.375	71	1.77	40.1	.642
24	24	0.375	95	3.14	30.3	.485
30	30	0.375	119	4.91	24.2	.387
36	36	0.375	143	7.07	20.2	.324
42	42	0.375	167	9.62	17.4	.279

[a] Referred to water at 62.4 pcf.

and scour associated with rivers and offshore locations. In river and offshore installations in which lines are laid without trenching, weight must be applied to the pipe to make it resist the resultant of buoyancy and current forces. For buried lines, for which a ditch is dug and the pipe is pulled in place, but not mechanically backfilled, the pipe must be weighted sufficiently for the pipeline to stay in place during the backfilling period. The pipe must resist movement in the face of sediment-laden suspensions, currents, and scours, while it is being covered by the process of natural sedimentation.

In flooded areas, pipeline anchorage is usually restricted to application of weight. A system of concrete or steel weighting materials is added to bring the bulk density up to the desired level. Anchorage is dependent on weight when laid under water because it is usually more difficult and more expensive to do anything else. When pipe is laid in an intermittently wet and dry area, the pipe might be laid in a dry season and a variety of methods can be used to anchor the line.

Most common methods of weighting are a continuous coating of concrete or asphaltic material uniformly applied to each joint of pipe. Application is usually by a rotating process to aid uniformity, and the material is additionally reinforced with wire or mesh to prevent the thin application of weighting material from spalling off the pipe when cracks occur.

Concrete weighting can be applied by means of precast concrete "set-on" weights. These are horseshoe-shaped concrete masses that straddle the pipe at predetermined spacings to furnish weighting. Precast concrete weights are also available in bolt-on sections that encircle the pipe.

Cast iron river weights were an early form of river weighting. River weights are still being used. Heavy-wall pipe is used in some instances to weight the line, but this is an economical solution for pipes in smaller sizes only. A wrapping of plate is another common method used to increase weight of the pipeline with steel.

Engineers are currently making more extensive use of mechanical anchors to hold down the line across seasonally flooded areas. Anchors can be used if soil and moisture conditions are favorable. Where they apply, such anchors can be installed more economically than can gravity-anchorage systems resulting from application of concrete or steel weighting material.

The most common anchorage system used on pipelines is natural backfill. In many instances pipelines have been subjected to unexpected surface flooding and temporary saturation with never any danger of flotation. In natural consolidated backfill, friction, cohesion, weight of overburden, and even vegetation prohibit the movement of the pipe. Except for rivers and offshore installations, pipeline anchoring problems are most critical during and immediately after construction. Application of anchorage is chiefly an aid to construction to get the pipe backfilled and to prevent movement of the line during the initial period of operation. After backfill becomes consolidated, instances of pipe flotation are rare even in areas of relatively poor soil conditions.

When backfilling with suitable compacted materials, pipe flotation may never be a problem even in areas subject to flooding. Overburden alone results in a significant anchoring force over a large diameter pipeline. Basic characteristics noted in research work (1)[1] done by one corporation are that the sediment must act as a fluid for the pipe to float, and bulk specific gravity of the pipeline has to be less than the specific gravity of the sediment.

Certainly these are truisms, but they clarify the issue. The second condition is easily fulfilled for gas lines. Except in instances of poor soils or in cases of extreme disturbance, backfill materials retain soil properties and do not act as fluids. The overburden must become liquefied for a pipeline to float out of a prepared ditch that has been mechanically backfilled.

RESULTS OF QUESTIONNAIRE BY PIPELINE FLOTATION TASK COMMITTEE

In September, 1959, a questionnaire to survey methods for weighting and for providing negative buoyancy for pipelines in waterflooded areas was sent by this committee to thirty-four pipeline companies, consultants, and contractors. Answers were received from companies handling products in three chief fields of pipeline activity: gas, crude oil, and petroleum products. Seventy-five instances of pipeline construction in water and water-bottom

[1] Numerals in parenthesis—thus; (1)—refer to corresponding items in the Bibliography.

areas were reported. It should be pointed out that these are sample cases only and should not be misinterpreted as being representative of all water-bottom or river crossing pipelines. Replies to the questionnaire are summarized in Table 2.

Eight offshore gas pipelines were reported, all off the coast of Louisiana. Weighting materials were used on all these lines ranging in size from 10 in. to 26 in. Bulk specific gravity of these offshore gas pipelines ranged from 1.28 to 1.55. Average for all eight lines is 1.41 relative to sea water at 64 pcf.

Eight gas pipelines and two crude oil pipelines in Louisiana marsh are tabulated. All these lines, including the crude lines, are weighted. Bulk specific gravity for gas lines and for crude lines considered full, ranged from 1.09 to 2.26 with an average of 1.33. Specific gravity in these instances is based on salt water at 64 pcf. In addition, ten gas pipelines across lakes, bays, and other fresh water areas are reported. Specific gravity of these lines ranges from 1.11 to 1.42 with an average of 1.27, all relative to fresh water at 62.4 pcf.

Widest variation of weighting practice encountered is relative to river crossings. Forty separate river crossings of gas, products, and crude oil lines were reported. All the river crossings were weighted in some fashion. Specific gravity of gas lines ranged from 1.06 to 2.0 with an average of 1.30 all relative to fresh water. Specific gravity of crude oil and products lines ranged from 1.00 to 1.91 empty and 1.58 to 2.47 when filled. Averages were 1.36 empty and 1.86 filled.

As can be seen by the tabulation, there is a wide variation in pipeline weighting or anchoring across rivers and water bottoms. For instance, pipeline cover in river crossings varied from 20 ft to nothing on the same river, that is, the Mississippi. Eight crossings of the Mississippi River were reported. Three of these were laid on the bottom without cover. Furthermore, even though there are wide variations in procedures for anchoring pipelines and crossing streams, there have been no failures in the examples reported.

Procedures for laying pipelines have been somewhat arbitrary, but they have been successful. Based on this survey, it appears that the greatest progress or gain from a study of laying pipelines in waterflooded areas can be made in the realm of economics.

FORCES ACTING ON THE PIPELINE

Except for mechanically anchored pipelines, the stabilizing force is chiefly gravity. When lines are buried with suitable soil for cover, cohesion and friction in the soil are important forces acting to hold the pipe in place. Gravity acting on the metal of the pipe, the contents of the pipe, the overburden over buried lines, and any weight additives placed on the pipe provides a downward pull. Contents of the line in liquid service make a significant contribution to holding the line in place.

A principal disturbing force that acts on pipelines in inundated areas is the buoyancy of water. According to Archimedes principle, "a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid." For large diameter gas lines, buoyancy is a large force acting constantly on the pipe. This force must be resisted. When subjected to fluid overburden, materials such as high-density suspensions, bed loads of streams and non-cohesive muds, and buoyancy forces become still larger and form the criteria for pipeline anchorage design in many instances.

TABLE 2.—SUMMARY OF REPLIES—SEPT. 1959 QUESTIONNAIRE

Item (1)	Miles (2)	Cover, in feet (3)	Soil (4)	Pipe Size, in inches (5)	Protective Coating, in inches (6)	Weighting (7)	Specific Gravity[a] (8)
(a) Offshore Installations							
1. Gas Lines—Offshore Louisiana							
East Cameron (2 yr)	25.3	6 (No BF)	2.0-2.06 Sand 1.35-1.72 Clay & Silt 1.7-2.2 Beaumont Clay	26 x 0.500	6/32 CT	3-5/8 in. (190 lb) CC	1.51
Eugene Island (8 yr)	15	3 (No BF)	1.3-1.7 (Average 1.43) Soft gelatinous mud near shore; silty clay	20.5 x 0.750 (1/4 in. Plate Wrap)	5/8 Som Asph. Mastic	1 in. (140 lb) CC	1.34
Chandeleur Sound (6 yr)	10	- (No BF)	Soft org. clay to silty clay	20 x 0.344	3/16 CTW	2-1/2 in. (165 lb) CC	1.28
West Cameron (1 yr)	23	3 to 10 (No BF)	3 mi.-sand 10 mi.-medium clay 10 mi.-Beaumont clay	16 x 0.375	4-/32 Asph. W	2-1/2 in. (140 lb) CC	1.36
Vermilion (1 month)	5	3 (No BF)	Soft clay, sand, and shell	14 x 0.500	4/32 CTF	1-3/16 in. (140 lb) CC	1.38
Main Pass (2 yr)	3.5	3	3 ft cover for protection out to 12 ft depth, then laid on bottom	12.75 x 0.375	3/16 CTW	1-3/4 in. (165 lb) CC	1.55
Breton Island Pass (6 yr)	10	3	3 ft cover for protection out to 12 ft depth, then laid on bottom	12.75 x 0.375	3/16 CTW	1-1/2 in. (165 lb) CC	1.48
West Delta (3 yr)	7.8	3	1.54 sp. gr. very soft gray clay	10.75 x 0.365	4/32 CTW	1 in (146 lb) CC	1.38
(b) Permanently Flooded Areas							
1. Gas Lines—Louisiana Marsh							
(In service 4 yr)	5	3		30 x 0.375	4/32 CT	2-3/4 in. (190 lb) CC	1.13

(3 yr)	117.7	-10MLG	-	24 x 0.406	6/32 CT	2-1/2 in. (165 lb) CC	1.18
(6 yr)	64.8	-	Soft Organic Clays Silty Clays	20 x 0.344	3/16 CTW	2-1/2 in. (165 lb) CC	1.28
(1 yr)	15	3	Org. clay-low shear Could not use anchors	16 x 0.312	5/32 Asph. W	2-1/4 in. (140 lb) CC	1.21
(2 yr)	7	3	-	16 x 0.375	5/32 CT	2-3/8 in. (137 lb) CC	1.33
(2 yr)	20	3	Not BF-laid in Canal Organic Soils	16 x 0.250	9/16 Som	1-1/2 in. (140 lb) CC	1.09
(1 month)	24	2.5	-	12.75 x 0.375	4/32 CTF	1 in (140 lb) CC	1.23
(3 yr)	24	-	Not BF-laid in 12 ft Canal	12.75 x 0.312	None	1 in (170 lb) Timcoat	1.22
2. Crude Oil Lines—Louisiana Marsh							
(1 yr)	28.3	3	1.27 sp. gr. soft gray clay W/org. matter	16 x 0.250	9/16 Som.	None	0.67
					Line Full (0.83 Sp. Gr. Crude)		1.34
(4 yr)	46.2	2.5	-	12.75 x 0.500 12.75 x 0.312	5/32 CT	1-7/8 in. (190 lb) CC	1.66
					Line Full (0.85 Sp. Gr. Crude)		2.26
3. Gas Lines—Other Areas[b]							
Lake Pontchartrain (1 yr)	26	3	Not BF-Organic & Silty clays	30 x 0.469	5/8 Som.	2-3/8 in. (190 lb) CC	1.21
Lake Pontchartrain (6 yr)	9.2	3	Sandy	20 x 0.344	3/16 CTW	2-1/2 in. (190 lb) CC	1.42
Lake of Two Mts.		3	-	20 x 0.500	3/16 CT	2 in. (145 lb) CC	1.29
Quebec (2 yr)	3						
Bay—Texas Coast (3 yr)	3	5	-	30 x 0.469	4/32 CT	3-1/4 in. (190 lb) CC	1.30
Lake-Kentucky	1.2	3	-	30 x 0.500	5/32 CT	3-1/16 in. (190 lb) CC	1.31
Lake - N. Texas	0.2	3	-	18 x 0.312	3/32 CT	Clamps-Conc (140 lb) 5,810 lb 50 ft	1.11
Tenn. River Bottom Swamps (1 month)	2	2.5	-	30 x 0.500	3/32 CT	Clamps-Conc. (140 lb) 6,200 lb @ 14 ft	1.20

TABLE 2.–CONTINUED

Item (1)	Miles (2)	Cover, in feet (3)	Soil (4)	Pipe Size, in inches (5)	Protective Coating, in inches (6)	Weighting (7)	Specific Gravity[a] (8)
(b) Permanently Flooded Areas							
3. Gas Lines—Other Areas[b]							
Atlantic Seabord Marsh	3	5	-	30 x 0.469	4/32 CT	3-1/4 in. (190 lb) CC	1.30
N. Ontario Muskeg (1 yr)	2 to 10	3	Muskeg	30 x 0.375	3/32 CT	Clamps-Conc. (220 lb) 9,500 lb @ 24 ft	1.25
N. Indiana Peat Bog (3 yr)	0.5	3	Spongy Peat	22 x 0.281	1/16 Wrap	Clamps-Conc. (143 lb) 2,500 lb @ 7 ft	1.31
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)[b]
(c) Rivers							
1. Gas Lines—Rivers							
Little Blue-Neb. (1 yr)	0.22	8.1	Silty Sand	36 x 0.438	3/32 Asph.	Clamps-Conc. (150 lb) 6,296 lb @ 9.9 ft	1.14
Smoky Hill-Kans. (1 yr)	0.11	6.2	Sandy Silt	36 x 0.438	3/32 CT	Clamps-Conc. (150 lb) 6,296 lb @ 11.7 ft	1.06
Kern R. (10 yr)	0.1	7	-	34 x 0.500	Triple W	Clamps-CI (450 lb) 4,200 lb @ 15 ft	1.06
Mojave B (7 yr)	0.41	8	-	34 x 0.500	9/32 CTF	Clamps-Conc. (160 lb) 13,650 lb @ 21 ft	1.28
Delta-Portland (1 yr)	0.75	8.5	Not BF-Sand, Clay	30 x 0.656	5/8 Som.	3-1/4 in. (190 lb) CC	1.50
Brazos (1 month)	0.15	10	1.0 to 1.8 Sp. Gr. Tan Silty Sand, Clay	30 x 0.625	3/32 CT	3-1/8 in. (190 lb) CC	1.40
S. Louisiana (4 yr)	1.0	15	-	30 x 0.625	4/32 CT	2-5/8 in. (190 lb) CC	1.30

Kapos Kasing-Ont. Dual (1 yr)	0.6	4	-	30 x 0.500	3/16 CT	Clamps-Conc. (145 lb) 6,200 lb @ 15 ft	1.20
Canada (Proposed)	0.7	5	1.15 Sp. Gra.	26 x 0.500	11/16 Som	2 in. (140 lb) CC	1.10
Mojave A (10 yr)	1.0	7	-	26 x 0.500	5/8 Som	Clamps-Conc. (148 lb) 4,900 lb @ 21 ft	1.19
Miss. Destrahan Dual (3 months)	3.0	-	Not BF-Sandy Clay (Dredged)	24 x 0.625	5/8 Som	2-1/4 in. (165 lb) CC	1.40
Red-Dual (1 yr)	0.9	20	Clay, Silt, Sand, Gravel	24 x 0.500	4/32 CT	2-1/8 in. (190 lb) CC	1.30
Pennsylvania (5 yr)	0.06	3	-	24 x 0.500	5/32 CT	Clamps CI (450 lb) 3,115 lb @ 15.6 ft	1.46
Miss.-Iowa (12 yr)	0.5	2.5	Silty Sand	22 x 0.375	3/32 CT	Clamps CI (450 lb) 1,400 lb @ 8.75 ft	1.33
Miss.-Ill. (8 yr)	0.46	15	Fine Sand	21.25 x 0.938 (5/8 in. Plate Wrap)	3/32 CT	None	1.32
Miss.-La. (1 yr)	1.0	20	1.2 Sp. Gr. Silt	20 x 0.500	5/8 Som	2-3/8 in. (140 lb) CC	1.35
Trinity Tex. (1 yr)	0.05	3	-	20 x 0.375	3/32 CT	Clamps-Conc. (140 lb) 4,000 lb @ 24.4 ft	1.17
Dry Creek (4 yr)	0.04	5	-	16 x 0.281	Triple W	2-1/2 in (130 lb) CC	1.20
Bear R. (4 yr)	0.15	5	-	16 x 0.281	Triple W	2-5/16 in. (130 lb) CC	1.17
Miss.-La. (3 yr)	0.5	0	Not BF	12.75 x 0.500	None	Clamps CI (450 lb) 1,230 lb @ 18 ft	2.00
2. Gas Lines—Rivers Seasonally Flooded							
Angelina-Tex. (8 yr)	0.35	5	Sandy Clay	31.25 x 1.125 (5/8 in. plate wrap)	3/32 CT	None	1.08
inundated	0.17			30 x 0.500	3/32 CT	Clamps-C. 1 (450 lb) 5,350 lb at 15.9 ft	1.40
Neches-Tex.	0.65	4.4	Sandy Clay	31.25 x 1.125 (5/8 in. plate wrap)	3/32 CT	None	1.09

TABLE 2.—CONTINUED

Item (1)	Miles (2)	Cover, in feet (3)	Soil (4)	Pipe Size, in inches (5)	Protective Coating, in inches (6)	Weighting (7)	Specific Gravity[b] (8)	
(c) Rivers								
2. Gas Lines-Rivers Seasonally Flooded								
inundated	0.13		Sandy Clay	30 x 0.500	3/32 CT	Clamps-C. 1 (450 lb) 5,350 lb at 13.5	1.54	
Guadalupe-Tex. (1 month)	3.5	4	1.4 sp. gr. soft organic silty clay	30 x 0.406	3/32 CT	Anchors-Chance 10 in 12,000 lb/set at 20 ft for class 7 soil min. 300 lb/lin. ft.	1.40	
Arkansas-Ark. (8 yr)	0.97	8	Silty Sand	25 x 1.000 (1/2 in. plate wrap)	3/32 CT	None	1.22	
inundated	0.03			24 x 0.500	3/32 CT	Clamps-C. 1 (450 lb) 1,960 lb at 11.4 ft	1.36	
Miss. (Greenville) (3 yr)	2.0	2.5	Flood Plain	24 x 0.500	5/32 CT	2-1/2 in. (140 lb) CC	1.16	
Penn.-overflow above river (5 yr)	0.24	2.5	-	24 x 0.500	5/32 CT	Clamps-Conc. (140 lb) 3,600 lb at 18.2 ft	1.15	
3. Crude Oil & Products—Rivers							Empty	Filled
Cimarron-Okla. (7 yr)	0.23	4	Sandy (dewatered)	24 x 0.500	3/16 CTW	Clamps-Conc. (143 lb) 5,370 lb at 20 ft	1.27	1.75
Arkansas-Okla.	0.65	4	(Dredged)	24 x 0.500	3/16 CTW	Clamps-Conc. (143 lb) 5,370 lb at 20 ft	1.27	1.75
Missouri-Mo. (7 yr)	1.4	4	(Dredged)	31%-24 x 0.500 69%-24 x 0.344	3/16 CTW 3/16 CTW	Clamps-Conc. (143 lb) 2,190 lb at 6.75 ft	1.34	1.79
Mississippi-Ill. (7 yr)	2.98	4	(Dredged)	22 x 0.500	3/16 CTW	5,370 lb at 18 ft & 14 ft	1.19-1.30	1.67-1.68

Illinois-Ill. (7 yr)	0.49	4	(Dredged)	22 x 0.500	3/16 CTW	Clamps-Conc. (143 lb) 2,200 at 6.75 ft 5,690 at 20 ft 2,410 at 7 ft	1.44 1.39 1.46	1.84 1.83 1.85
Maumee-Ohio (2 yr)	0.14	4	-	20 x 0.500	5/32 dbl W	Clamps-Conc. (143 lb) 4,434 lb at 30 ft	1.19	1.67
Miss. (Destrahan) (1 yr)	0.5	0	Loose to med. dense sand	20 x 0.500	5/8 Som.	1-7/8 in. (165 lb) CC	1.40	1.88
Creek-Swamp-Tex. (1 yr)	0.85	5	-	20 x 0.281	3/32 sgl W	Clamps-Conc. (143 lb) 2,217 lb at 14.5 ft	1.06	1.58
Greens Bayou-Tex. (1 yr)	0.02	5	(By Crane)	20 x 0.312	5/32 dbl W	Clamps-Conc. (143 lb) 4,434 lb at 15 ft	1.31	1.64
Spring Creek-Tex. (1 yr)	0.05	5	(Dewatered)	20 x 0.281	5/32 dbl W	Clamps-Conc. (143 lb) 4,434 lb at 29 ft	1.00	1.48
Richland Crk-Tex. (1 yr)	0.02	4	-	18 x 0.281	3/32 sgl coat dbl W	Clamps-Conc. (143 lb) 2,094 lb at 20 ft	1.03	1.58
Raritan—N. J. (5 yr)	0.16	4	-	16 x 0.500	9/16 Som.	2-1/8 in. (190 lb) CC	1.72	2.08
Miss. (Nairn) (1 yr)	0.6	0	Loose Silty Sand	16 x 0.500	9/16 Som.	1-3/8 in. (140 lb) CC	1.39	1.86
Red-Okla. (4 yr)	1.03	10	-	16 x 0.500	3/16 CT(Yard)	Clamps. Conc. (143 lb) 2,797 lb at 14.2 ft	1.62	1.98
Colorado-Ariz. (2 yr)	0.2	12.4	Loose Sand	16 x 0.500	3/32 CT	1 in. (140 lb) CC	1.25	1.82
Wabash-Ill. (20 yr)	0.09	3	-	13 x 0.500	None	-	1.16	1.87
S. Jacinto-Tex. (6 yr)	0.12	5	-	12.75 x 0.500	3/32 dbl CW	Clamps-Conc. (143 lb) 987 lb at 15 ft	1.56	1.98
Wabash-Ill. (20 yr)	0.09	3	-	6.625 x 0.288	None	-	1.30	2.00

TABLE 2.—CONTINUED

Item (1)	Miles (2)	Cover, in feet (3)	Soil (4)	Pipe Size, in inches (5)	Protective Coating, in inches (6)	Weighting (7)	Specific Gravity[a] (8)	
(c) Rivers								
3. Crude Oil & Products—Rivers							Empty	Filled
Cincinnati—Ohio (18 yr)	0.28	3	Silty Clay	6.625 x 0.432	None	-	1.91	2.47
Ohio—Ind. (2 yr)	0.15	3	-	4.5 x 0.237	None	-	1.56	2.47

Abbreviations: BF - backfill; Som - Somastic asphalt mastic; CC - Continuous concrete (density of aggregates indicated); CTW - Coal tar wrap coating; CTF - Coat tar felt wrap

[a] Referred to sea water at 64.0 pcf unless otherwise indicated.
[b] Referred to fresh water at 62.4 pcf

TABLE 3.—SAMPLE COMPUTATIONS FOR RIVER CROSSING[a,b]

Sample No. (1)	Depth in Feet (2)	Classification (3)	Water Content (4)	Atterberg Liquid Limit[c] (5)	Absolute Specific Gravity (6)	1 Blow: Water Content % (7)	1 Blow: Mass Spec. Grav. (8)	0.1 Blow: Water Content % (9)	0.1 Blow: Mass Spec. Grav. (10)	0.01 Blow: Water Content % (11)	0.01 Blow: Mass Spec. Grav. (12)	0.001 Blow: Water Content % (13)	0.001 Blow: Mass Spec. Grav. (14)
13	2.5	Very soft gray clay with organic matter	91.6	120	2.67	148	1.34	168	1.30	188	1.27	208	1.25

[a] Typical Mass Specific Gravity Determination of Subsoil Liquid Stage.
[b] Pipeline should be coated to provide a minimum specific gravity of 1.27.
[c] See ASTM Specification D 423 for definition of "Liquid Limit."

Additional disturbing forces are scours and currents that occur during river floods and offshore storms. In many instances these unpredictable forces are the principal causes for weighting pipelines. This is the chief reason for the arbitrary weighting criteria used in the pipeline industry.

Because of the inaccessible condition of submerged pipelines and the difficulties in handling them, the addition of weighting materials is the most expedient and practical method of anchoring underwater lines. In the pipeline industry, the amount of weighting applied is expressed in terms of specific gravity of the pipe, contents, and added weighting materials.

When pipelines are buried in offshore and river installations, the weight is applied, in many instances, to keep the pipe in place so that it will be covered. Cover usually is obtained by natural sedimentation. Trenching is required to protect the pipe from scouring, from dragging of anchors, and from any mechanical damage to which the pipe might be subjected. For buried lines, weight must be applied very heavily to keep the pipe on the bottom and to resist all forces of movement in the face of scours, current forces, and sediment suspensions.

CONSIDERATIONS GIVEN TO DETERMINATION OF WEIGHTING

Current flow in a river around a suspended pipeline causes it to alternately rise and fall as equilibrium conditions vary in the current, until the line is literally flexed to fatigue and resultant rupture. This condition can be prevented if sufficient weight and slack length of line are provided so that, in the event of bottom scouring, the line can lower itself to the new bottom, preventing flow around the pipe capable of lifting the line up into the full force of the stream (2).

A pipeline company constructed a river crossing on a major river, taking great care to dredge a trench for the line to achieve a final minimum cover of 5 ft below the river bed. After installing the pipeline, the trench was left to be backfilled by sedimentation. Later examination showed that the line had no cover at all, but lay on the bottom of the river 5 ft above its original position and was completely exposed to all hazards inherent to that location. This occurred despite the fact that concrete coating had been added (3) to provide a negative buoyancy of 25 lb per lineal ft.

A number of pipelines laid in the marshes in Louisiana and Texas, even though weighted to provide various amounts of negative buoyancy, have become exposed to the extent of being clearly visible from the air above the marsh lands shortly after installation. Although the lines had been designed with a specific gravity in excess of 1.0, not enough consideration had been given to the buoyancy of disturbed silt and clay with a density considerably in excess of that of water.

Actual samples taken from the bottom of several major rivers that are heavy silt carriers (3) weighed as much as 80 pcf to 85 pcf, corresponding to a specific gravity of 1.28 to 1.36. Tests indicated that in a number of samples, the critical density of the liquid was reached as settlement began and just before the heavier portion of the mixture ceased acting as a liquid and began acting as a solid. Method of trenching has considerable effect on pipeline weight requirements because dredging action can create the dense liquids referred to in these tests.

Some pipeline companies use soil consultants to investigate soils along the right of way, to determine their characteristics and to propose methods to provide stability. Material from the right of way is subjected to mechanical agitation and continuous hydrometer readings are taken during agitation, settling and consolidation. Hydrometer readings are used to determine the maximum densities that can be obtained with the mixture to estimate its highest probable displacement value.

One consultant has devised a method of estimating the critical density of fluid overburden materials from the liquid-limit test. Procedure for conducting the test follows the liquid limit test as outlined in ASTM Specification D423. Result of sample testing is plotted for blows versus water content for the sample. The curve is extended to 0.01 blow and the the water content determined at this point. Water content at 0.01 blow is assumed to be the critical condition at which soil and liquid mixture react as a fluid with little or no shear strength, the condition that produces maximum buoyancy on the pipeline. Fig. 1 shows the graphical procedure for making this determination (4). After determining the water content, at 0.01 blow, mass specific gravity of the soil-water mixture in this condition is computed. Pipeline is then designed to provide this minimum bulk specific gravity in areas of fluid overburden materials as shown by the sample form, Table 3. Thickness of continuous weighting to develop this required bulk specific gravity is computed in the manner shown in Fig. 2.

Problems connected with stability of pipelines have only recently begun to be properly considered. However, with the limited work that has been done, some few rules have been developed. The following concepts have been brought out in investigations by industry when planning specific pipeline installations:

1. Light submerged bodies, specific gravity of 0.5 or less, work their way through fine sand typical of beach sand (1).
2. Bodies with densities between that of water and sand have little or no tendency to ascend through fine sand.
3. If a pipe is buoyant in water, it is very likely to float out of sand or silt due to action of waves.
4. If a pipe is buoyant in a liquefied sediment, agitation of the sediment will cause it to rise.
5. In order for a pipeline to float (a) the sediment has to act like a fluid, and (b) bulk specific gravity of the pipeline has to be less than the specific gravity of the sediment.

These statements raise the question of what is required to liquefy soil. Answers will vary with overburden material and will depend on prevailing hydrographic, mechanical, and oceanographic conditions. These previous concepts are based on density characteristics only. Serious consideration must also be given to the shear strength properties of soils such as cohesion and friction. Liquefaction of some materials might never be a problem when inherent strength of the material would prohibit a breakdown of the grain structure by natural phenomena.

ANCHORING OF OFFSHORE PIPELINES

Plans for any offshore pipeline should be preceded by a study of oceanographic and hydrographic conditions in the area of interest. All factors that

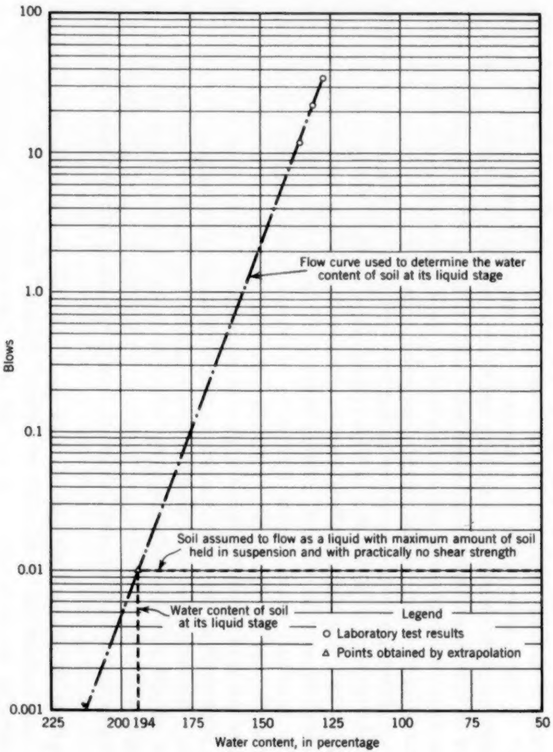
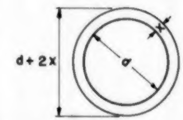


FIG. 1



1. PIPE SIZE: 30" GAS PIPELINE
2. PIPE WEIGHT: 128#/LIN. FT.
3. DESIRED BULK SPECIFIC GRAVITY = 1.27
4. DESIRED BULK DENSITY = 1.27 x 62.4 = 79.2#/FT.^{3}
5. PIPE - O.D. 30"
6. PROTECTIVE COATING: 3/32"
7. WEIGHT OF PROTECTIVE COATING: 7.11#
8. DIAMETER, PIPE & WRAP, d = (5) + 2(6) = 30 + 2 (3/32) = 30.19" OR 2.52'
9. VOLUME OF WEIGHT COATING = $\pi(dx + x^2)$
10. VOLUME OF PIPE & COATING = $\frac{\pi}{4}(d + 2x)^2$
11. WEIGHT OF PIPE & COATING = (10) x (4) = $\frac{\pi}{4}(d + 2x)^2 \times 79.2$
12. WEIGHT OF COATING = (11) - (2) - (7) = (11) - 128 - 7.11 = (11) - 135.11
13. SELECT DESIRED DENSITY OF WEIGHT COATING 165#/FT.^{3}
14. SOLVE FOR THICKNESS OF COATING, X:

WHERE DENSITY OF COATING = $\frac{\text{WEIGHT OF COATING}}{\text{VOLUME OF COATING}}$

$$(13) = \frac{(12)}{(9)}$$

$$165 = \frac{\frac{79.2\pi}{4}(d + 2x)^2 - 135.11}{\pi(dx + x^2)}$$

SUBSTITUTING 2.52 FOR d, LINE (8), REDUCE & SOLVE FOR X
X = .34 FT OR 4.1"

FIG. 2.—SAMPLE CALCULATION THICKNESS OF CONTINUOUS WEIGHT COATING

may affect the life or continuous operation of the pipeline during its planned period of service should be evaluated. Records should be obtained relating to early shore positions and previous contours of the ocean bottom along the expected route of the pipeline.

A survey or study for any location is required to develop specific oceanographic factors at that particular site. When operating conditions permit, study of hydrographic charts, maps, aerial plots, and other records together with ground studies should determine the selection of the route. If it is possible to do so, an accreting shore should be selected for the pipeline to traverse the surf. In many cases, little can be done to alter the route of a proposed pipeline. But if positioning is possible, the orientation of the line should be based on oceanographic conditions of the area. There are indices that point toward a desirable versus an undesirable section of beach (5). Erosion and scour are principal hazards to pipelines traversing surf and beach. Active or less desirable bottoms are indicated by the presence of sand, shell, or sand and shell. Hard mud bottoms usually indicate little or no surf activity.

Proper vertical cover for a pipeline across the beach and surf is a subject of conjecture. Federal regulations require that offshore pipelines be buried out to the fifteen-foot contour. Three feet of cover is specified to prevent damage from anchoring vessels in the shallow water. Extra depth is often provided near the shore. As a practical guide to help gage the proper amount of cover for offshore pipelines, it has been noted that a vertical erosion of 6 ft during a single hurricane occurred off Palm Beach on the east coast of Florida.

In the area beyond the 15-ft contour, some pipelines in the offshore are not buried. There are conflicting opinions among operators regarding the need for burying deep water pipelines. One company has had an experience that makes a strong case for burying offshore pipelines. During hurricane "Flossy" in September, 1956, this company had several costly pipeline moves and breaks in unburied lines. Pipeline sections with specific gravities ranging from 1.4 to 1.65 were moved as much as 1,400 ft. Some of the pipeline movements were in water depths approaching 50 ft. On the other hand, buried lines in the same area experienced no movement or damage.

For offshore lines that are to be buried, enough weight must be supplied for the line to stay in place during backfilling. One method for laying offshore lines is to dig the trench along the pipeline route, place the pipeline in the trench, and depend on natural sedimentation to supply backfill to cover the pipe. The pipeline must resist buoyancy of water and soft fluid overburden materials to stay in its position and be covered. In addition to buoyancy for the pipe to remain covered, other unpredictable water forces must be resisted such as currents, scours, and water movements caused by waves.

So far, the only practical method of anchoring that has been developed for offshore pipelines is deadweighting. Weight is supplied to hold the pipe in place on the bottom of the trench. Optimum weighting criteria are needed for offshore pipelines so that safe anchoring can be obtained at the lowest possible cost.

A method of deadweighting that has been used successfully in getting offshore lines buried is to develop a volume density in the pipeline equivalent to the density of the ocean bottom material into which the pipeline is to be laid. Because of disturbance and dilution during the trenching and sedimentation processes, the density of the fluid backfill will certainly be less than the mean density of the sediments removed.

Because most of the examples studied in this investigation are located off the coast of Louisiana, pipe weighting practice will be described for the Gulf of Mexico. Ocean bottom sediments nearest the mudline in the Grand Isle Area of the Gulf of Mexico have an in-place density of approximately 90 pcf. Related to salt water, a bulk specific gravity of 1.4 provides a density of 89.6 pcf. From experience in pipe laying in the Grand Isle Area, it has been found that pipelines laid with a specific gravity of 1.4, that is very nearly the density of the in-place sediments, have sufficient density to stay in place during a normal backfilling period. In adjoining areas with soils of greater densities, a slight increase in shear strength is noted. A specific gravity of 1.4 has been used satisfactorily for laying pipelines in these areas of better soil conditions. So long as the soil has some cohesion or shear strength and is not completely disturbed, it is doubtful that buoyancy equivalent to that of a fluid with an in-place density of the material ever takes place.

Correct weighting for unburied lines will depend directly on oceanographic conditions in the area of the pipeline. To prevent movement and to provide maximum protection for pipelines against interruption of service, offshore lines should be buried.

RIVER CROSSING PROCEDURE

River crossing constitutes one of the most important phases of ordinary pipeline construction. Useful life of the pipeline may be largely determined by the durability of its important river crossings and its resistance to corrosion. Although actual pipe length involved in river crossings is minute relative to total length of the pipeline, river crossings should receive the "lion's share" of planning and engineering because river hazards are potentially so enormous.

River crossing problems become so complicated and expensive that one gas company actually bought an existing highway toll bridge across the Mississippi at Greenville, Mississippi for pipeline crossings. A number of its lines already existed on the bridge and other crossings were added. Security of the pipeline rests mainly in the river crossings because a break here is the most difficult to repair. A failure of a large river crossing might not be repaired, because it might be cheaper and easier to lay a new line across the river. The history of river crossing failures attests to the seriousness of these problems.

In preparation for an important river crossing, an extensive review of river history and hydrographical data should be made. Aerial photographs, hydrographic maps, property ownership maps, and caving bank survey drawings are useful in making a study of this type. If any latitude is permitted by operations, a site should be selected at which banks and bottom of the river are stable. If bank recession is occurring, provision should be made for extra cover during the proposed life of the pipeline. Past records of bank recession should give a reasonable prediction for future bank activity along the river. Stream data regarding speed of current and depth of scour in the river bed is invaluable in designing a safe and economical crossing.

Submerged river crossings are dependent on weight for stability. For buried lines, weight provides the anchoring force required for the pipeline to be covered. Unburied lines depend wholly on gravity to resist the combined resultant of current and bed load buoyancy forces. Unburied lines must be weighted very heavily to resist current movement.

Rules for selection of proper weighting for a river crossing are difficult to set down. Sometimes it is useful to know the procedure and experience of other operators across the same river. If there is no history of previous crossings, then an extrapolation can be made with crossing conditions of rivers similar to the one in question.

River crossings have been satisfactorily made for gas lines with specific gravities ranging from 1.06 to 2.00. Amount of cover over buried pipe in the stream ranges anywhere from zero to 20 ft on the same river. River crossings have been proposed which provide depths of cover up to 40 ft. It is interesting to note that the 2.00 specific gravity is also associated with a Mississippi River pipeline crossing laid without trenching. River weighting is dependent on the character of the stream. River flow and river bed conditions vary so widely that many different crossing schemes are possible.

Scour is a major problem to be considered when installing a pipeline across an alluvial stream. Scour can mean failure to a pipeline river crossing. Scour is the cutting or "eating" away of the bed or banks of a river by flow in the stream. Extent and depth of scour are functions of bottom velocity and volume of flow. Highest velocity and deepest scouring occurs at the thalweg of the stream. Greatest hydrodynamic forces in the stream also occur here. Scour is dangerous to the pipeline because it removes overburden or cover from the pipe and can undermine it, exposing the pipe to other forces and hazards in the stream bed.

For unburied lines, scour is often provided for by installing slack loops or "sinusoidal curves" across the river. Theory behind this practice is that if erosion occurs the pipe and its coating will pull the line down, utilizing the slack provided to conform to the new bottom contour.

Many engineers advocate entrenchment below the scour line as the only safe way to cross rivers. This may well be true providing the trenching can be accomplished and the scour line can be accurately predicted throughout the useful life of a pipeline. Chief disadvantage of trenching across major rivers is an economic one. Trenching across wide and deep rivers is difficult and tremendously expensive. It has been found in some instances that several smaller lines can be completely installed on bottom and put into service for the cost of dredging alone for a single large pipeline. Several small lines provide a margin of safety in that if one line goes out, service can still be maintained through the remaining lines.

For buried river crossings, as in offshore pipelines, the density of the pipeline and its weighting should be at least equivalent to the density of fluid backfill material to which it is exposed. If the density of the bed load is to be computed, a sample of the material should be taken from the thalweg during periods of maximum flow. If it is not practical to do this, then samples of near-surface river bed material can be taken and placed into a fluid suspension. From this suspension, density of the simulated bed load can be estimated. In either case, a margin of safety should be provided to cover possible errors of unforeseen changes and nonrepresentative sampling. Weighting for unburied lines should be based on a hydrodynamic analysis of the stream.

PERMANENTLY FLOODED INLAND AREAS

Permanently flooded areas in terms of pipeline construction usually means lakes, bays, reservoirs, and flotation ditches in marsh crossings. Anchoring

in these installations almost always takes the form of continuously applied weight coatings. Continuous weight coating is a practical form of anchoring across these areas because of the ease of installation.

Current and scour in these cases is minimized. Oftentimes no effort is made to backfill the pipeline. Because water movement forces are of small consequence, and pipe is usually not backfilled, principal force to be resisted is buoyancy of water. Depending on local conditions, a small margin of safety in addition to specific gravity of water is all that is needed in these installations. As shown by part (b) of the pipeline survey, a specific gravity ranging from 1.11 to 1.25 is common for pipelines laid in these areas of quiet water activity. If the pipeline is to be buried, then steps as previously outlined should be taken to assure that burial can be satisfactorily accomplished; bulk specific gravity of the pipeline should be at least equivalent to the specific gravity of any fluid backfill material to which it might be subjected.

SEASONALLY FLOODED AREAS

In land areas immediate to the Gulf of Mexico, a region of concentrated pipeline activity, large quantities of pipeline weighting and anchorage are across seasonally flooded areas. Low coastal plains grade into the beach and large low-lying areas such as marsh, swamp, and flat river bottom land are common through Texas, Louisiana, and around the coast into Florida. Pipeline crossings through these occasionally inundated areas often require weighting or anchorage. In these areas engineers have an excellent opportunity to exhibit their skills because it is in these areas that the greatest savings in pipeline construction can be effected.

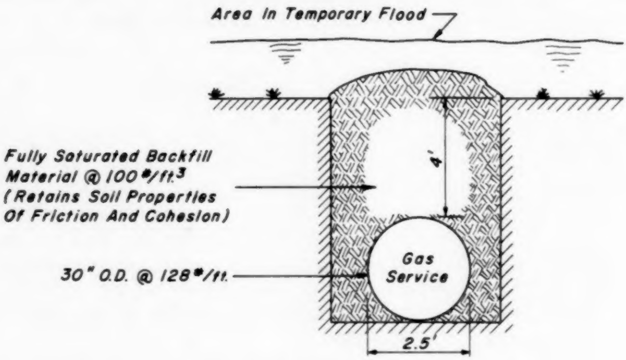
Through seasonally flooded areas, anchorage will depend on condition of the soil and on moisture conditions during the period of construction. In these areas, in which anchorage is required, many different methods can be used. Limitations using only weight for anchorage as in offshore lines and river crossings no longer applies.

With favorable soil and moisture conditions, and using proper precautions, large diameter gas lines may be laid without any anchorage other than natural backfill material. Fig. 3 illustrates the anchorage provided by natural backfill in seasonally flooded areas. If the pipe can be laid in a dry season and good compaction can be obtained in the backfill, no additional anchorage may be required.

If a gas pipeline must be constructed through these areas during flood season, weight is required to hold the pipe in the ditch until the backfill becomes consolidated. Pipelines in fluid service might avoid this stringent requirement by filling the pipe with water during construction and keeping the line filled with oil or products during service. Anchorage is sometimes required if the backfill becomes so disturbed during construction operations as to lose its soil properties.

Disturbance associated with pipeline construction is sufficient to break down cohesion and grain structure of soils with low shear strength in many cases. Breakdown comes as a result of digging and removing material in the trenching process, contact with free water in low-lying areas, and handling and placing involved in backfilling the material. In special cases for which backfill is in such a vulnerable condition, agitation of the backfill by river currents, flood waters, and waves in shallow water over submerged gas pipelines can provide the impetus that results in a floating pipeline.

Pipelines must be anchored to meet these fluid backfill conditions. Amount of anchorage will depend on the properties of the soil in the backfilled state. Representative samples of the material should be collected and tests run in a thoroughly remolded condition. Shear strength, moisture content, and density of the remolded or thoroughly disturbed material can be used as an index of the soil as backfill. If the soil does not retain its soil properties of friction and cohesion in the remolded condition and grain structure completely breaks down, density of the material at which it becomes a fluid is critical. Methods previously outlined, such as demonstrated on Fig. 1, can be used to determine this critical condition. Density of the material in this fluid state is the criterion that must be allowed for in design of pipeline anchorage.



Net Weight Of Soil Over Pipe $= 2.5 \times 4\,(100 - 62.4)$
$= 10 \times 37.6 = 376$ #/ft.

Buoyancy Of Gas Line $= \dfrac{3.14(2.5)^2}{4} \times 62.4 - (128)$
$= 306 - 128 = 176$ #/ft.

Ignoring Friction And Cohesion On Sides Of Overburden Mass, Factor Of Safety Against Floating Pipes $\dfrac{376}{176} = 2.14$

FIG. 3.—ANCHORAGE PROVIDED BY FAVORABLE BACKFILL IN SEASONALLY FLOODED AREA

In addition to buoyancy of backfill material, water forces in these low areas must not be overlooked. Effect of flooding in the newly placed backfill must be evaluated and provision made for effects of scour down the pipeline right of way.

Depending on topographical conditions, many different anchoring systems can be used across seasonally flooded areas. If the area is flooded or an inaccessible area must be traversed, a gravity anchoring system is most practical. In these cases, a continuous weighting of some type is preferred.

If the area is dry during construction, other alternates are possible. When backfill is favorable and it retains soil properties in the disturbed state, then

water is the buoyancy force that must be resisted. Backfill alone may be sufficient anchorage, with the depth increased, to provide more than usual cover over the pipe.

If fluid backfill is the buoyant force that must be resisted in addition to water, then mechanical anchors might be used to hold down the pipe. This is a relatively new development in laying large diameter gas lines. One mechanical anchor for pipeline installation is a helical screw installed at a depth well below the pipeline ditch into undisturbed soil. Spacing of the anchors will depend on soil conditions and should be determined in the field. When conditions are favorable, anchors can be installed more economically than gravity systems.

CONTINUOUS WEIGHT COATING

The two basic methods of continuous weighting are (1) using thicker-walled, heavier pipe, or (2) adding some type of weight to the line's exterior. The first is extremely expensive, for the cost of line pipe rises rapidly as the thickness is increased. Furthermore, in the manufacture of pipe, this extra thickness is added to the interior and may mean an appreciable reduction in capacity of the line due to a smaller inside diameter.

Disregarding heavier-walled pipe, a type of weight must be selected to overcome buoyancy. For many years the industry relied solely on cast iron or reinforced concrete river weights. In addition to the high cost of these clamps, installation was difficult. With a continuous weight coating, several miles of pipeline can be pushed from one location into inaccessible areas.

Continuous weight coating is applied by mechanical means to the entire length of pipe with the exception of cut backs at the end of each joint. These cut backs range from a maximum of 18 in. to a minimum of 9 in., depending on specification and type of protective coating. The general classifications of continuous weight coatings are concrete and asphalt mastic.

Continuous concrete weighting is applied over a corrosion prevention coating usually composed of the following: coal tar or asphalt enamel combined with glass or felt wrappers, or a combination of them; or asphalt mastic type coating. Although usually applied to add weight to the pipeline, concrete has another distinct advantage in that it provides additional mechanical protection for the corrosion coating and the pipe. Concrete offers mechanical protection particularly against barnacles and construction damage. However, barnacles exist only near the mud line in salt water and experience indicates they exist only on unburied lines and do not bother buried pipelines.

Concrete is available in three standard weights, 140 pcf, 165 pcf, and 190 pcf. Concrete weighing 140 pcf is composed of cement and sand. The sand is usually minus 3/8-in. or 1/4-in. mesh. This is usually the most economical on all pipe sizes for which specific gravity requirements can be met. Concrete weighing 165 pcf is composed of cement, sand, and a heavy aggregate. The heavy aggregate and sand are mixed at a volumetric ratio of 1-to-1. There are several materials used as heavy aggregates, such as barite, hematite, illmenite, and magnetite. The selection of the aggregate depends on the quality and cost; illmenite and magnetite are the most commonly used at present. Concrete weighing 190 pcf is composed of cement and a heavy aggregate. These heavier mixes of 165 pcf and 190 pcf are used on large diameter pipe, on which one wrap of wire reinforcing can be saved or on which it would be impractical because of thickness and weight to use a lighter ma-

terial. The maximum thickness to which concrete can be applied is indefinite and varies with the process used in application, thicknesses over 5 in. being rare. A minimum thickness of 1 in. is usually applied for reasons of practical application and the necessity of adequately covering the wire mesh reinforcing.

Concrete coatings are applied by a variety of procedures: impingement, extrusion, and casting. The impingement method is most common. This may be accomplished by a pair of rotating belts or brushes and by air. The air method is commonly known as guniting and is usually restricted to small river crossings and bends. Application units are fed by either a continuous mix or a batch mix depending on the applicator's equipment. In some instances concrete is applied by forming and pouring. This method is usually specified where extremely accurate weight requirements must be met or where the quantity of weighting is small.

Formed concrete develops a considerably lower strength than concrete applied by the impingement method but this can be offset by the use of electric welded reinforcement instead of woven wire mesh.

Woven wire mesh to reinforce the weight coating is applied during extrusion and impingement application. Proper control of operation permits placing reinforcing accurately in the thickness of concrete. The two wire mesh specifications in common use are 1-in.-by-1-in. mesh of 18-gage galvanized wire, and 1-1/2-in.-by-1-1/2-in. mesh of 17-gage galvanized wire. Width of mesh used varies between 3-3/4 in. and 6 in. The 1-1/2-in. mesh, 17-gage wire is least expensive and has a bonding area of 41.3 sq in. per sq ft of mesh compared to 58.2 sq in. per sq ft for 1-in., 18-gage mesh.

About 2-3/4 in. is the maximum thickness of concrete that can be adequately reinforced with one layer of mesh wire. A second layer of wire is usually specified starting between 1-3/4 in. and 2-3/4-in. thickness.

Curing is usually done by a curing compound sprayed on immediately after the concrete is applied. Water is seldom used. Joints are usually cured for one day before stacking and for 4 days before shipping.

The usual practice is to weight coat the welded joints for salt water lines and to omit it on inland pipelines. Coating the joints is expensive. The weight omitted on joints is frequently added uniformly over the concreted length between cut back ends. If field joints are to be concreted, the mesh reinforcing is allowed to project approximately 2 in. from the concrete cut back. This permits splicing of reinforcing for the concrete field joint.

Asphalt mastic coatings can be used for continuous weighting material under certain conditions, thus serving the dual purpose of corrosion protection and weighting. Asphalt mastics may have enough weight for pipe sizes through 12-3/4-in. OD. Conditions vary depending on weight of steel pipe used and the specific gravity required. Minimum weight of asphalt mastic is approximately 128 pcf. However, it is possible to add heavy aggregate that permits satisfying weight requirements on larger pipe.

Asphalt mastic coatings are generally more flexible and smoother than concrete and, therefore, may have some advantages in laying practice. All asphalt mastics presently used are extruded under pressure onto the pipe. No wire reinforcement is used.

ANCHORING PIPELINES WITH MECHANICAL ANCHORS (6)

In occasionally flooded areas and other areas in which pipeline anchorage is needed beyond that furnished by natural overburden, additional anchorage can be supplied economically with helical mechanical anchors.

To a limited extent, anchors have been used for 25 yr to prevent uplift of buried pipelines. Slow hand installation of anchors limited this application until 1957 when equipment and procedures for rapid installation using air driven tools were perfected. Because of the economy of mechanical anchors, an increasing number of these anchors have been used for anchoring pipelines in the few years prior to 1960.

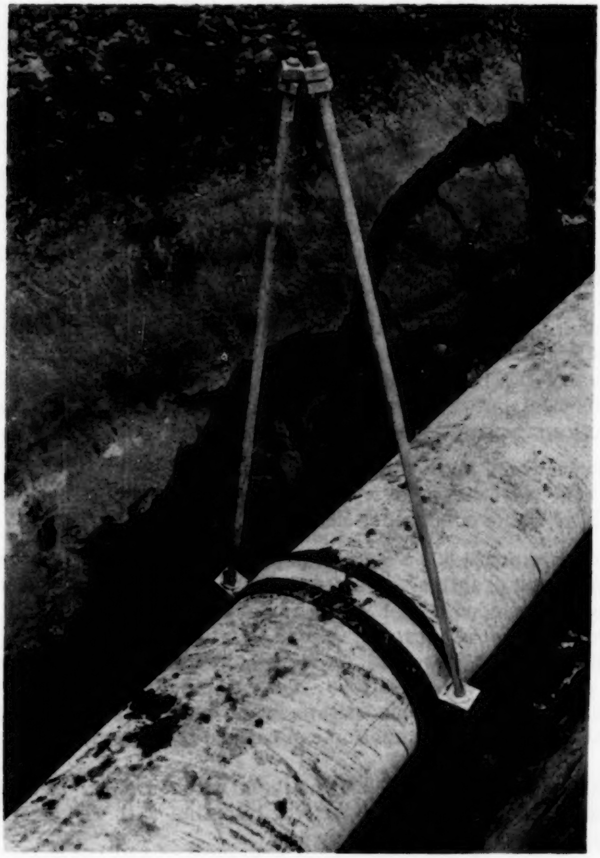


FIG. 4.—PIPELINE ANCHOR SET

A typical mechanical anchor set is shown in Fig. 4. Two anchors and pipe hold-down straps are shown in position for driving. Rock shield or pipeline felt between the pipe and strap prevents damage to protective coating on the pipe. The uniform helical shape of this anchor is designed to screw itself into the soil without excavation. Other types of mechanical anchors are also available but installation generally limits their application.

Anchor spacing is usually determined by the strength of the soil. Deflection of the pipe between anchors sometimes limits the spacing. Anchor selection regarding size of helix and length of rod and spacing should be worked out on the basis of field investigation in the immediate area of interest and anchorage requirements.

Oftentimes the ditch can be leveed off and pumped out, in other cases the pipe can be filled with water to submerge it for installation of the anchors.

CONCLUSIONS

The Task Committee on Pipeline Flotation was organized to study pipeline flotation problems. There is a definite need in the pipeline industry for a rational design method of determining optimum pipeline weighting.

As shown by a survey of current industry practices, pipeline anchoring has been largely guided by rule of thumb methods. In many cases in which arbitrary methods were used, there are many instances of questionable design. From the survey, except for submerged river crossings and offshore pipelines, many of the pipeline installations appear to have been overly conservative. There has been wide variation in pipeline anchoring through similar areas. No failures or dissatisfaction in regard to pipeline flotation have been noted in connection with any of the pipelines reported in this survey. Improved pipeline anchorage and important economic gains might be effected through a more realistic and technical consideration of pipeline anchorage.

Principles of the basic pipe flotation problem are relatively simple. For a pipeline to float out of a prepared ditch that has been mechanically backfilled, the following conditions must be satisfied:

1. The overburden materials must act as a fluid.
2. The bulk specific gravity of the pipeline must be less than the bulk specific gravity of the overburden materials.

A few tentative procedures have been established to apply these principles to field pipe laying practice. To determine the density of backfill material in its critical or fluid condition, hydrometer analysis and liquid limit test point the way toward technical approach to pipe flotation problems.

Across flooded and inaccessible areas, pipeline anchorage is usually restricted to application of some form of weighting material. In intermittently wet and dry areas, various anchoring procedures such as mechanical anchors or additional cover over the pipeline can be used to tremendous economic advantage.

Particularly in the use of backfill material with low shear strength, deeper trenches and increased cover over the pipeline will we better utilize the anchorage properties of natural materials.

RECOMMENDATIONS

From this review of pipeline flotation practices, it appears that the Pipeline Flotation Committee should initiate research toward developing better methods for determining critical density of backfill material. The liquid limit procedure described in the body of the report should be further validated

through additional testing. Techniques of hydrometer testing might be improved so as to be more pertinent. Methods not now being used might be developed. Research on critical density would have broad application to pipeline problems everywhere.

In the study of pipeline flotation thus far, emphasis has been on the density aspects of the problem. Greater consideration should be given to shear strength properties of soils. For pipeline work, the shear strength of soils in the remolded condition is critical. Pipeline anchoring systems should be more closely tailored to actual field conditions. This can be brought about by thorough topographic and soil surveys through areas at which pipeline flotation might be a problem.

Together with a study of remolded shear strength of soils, a method is needed to determine more accurately the time required for low shear strength backfill to reconsolidate. Low strength material is thoroughly disturbed during the construction of a pipeline. During and immediately after construction is the period of greatest vulnerability to flotation. More knowledge of the time of reconsolidation would permit a better evaluation of risk factors of pipeline flotation.

Specifically, the Task Committee makes the following recommendations:

A. To place the design of pipeline anchorage on a more technical basis, the committee should instigate a research program to perform the following functions:

1. Develop a field and laboratory testing procedure to determine whether specific backfill materials can become fluid.
2. Determine what mechanical agitation or natural phenomena are required to make low strength materials become fluid.
3. Perform additional testing on many different types of soil to validate the proposed liquid limit method of determining the critical density of low shear strength materials which can become fluids.
4. Investigate other procedures for finding critical density.
5. Develop a scale for measuring the relative time required for different thoroughly disturbed backfill soils to reconsolidate and regain shear strength to be stable overburden materials.
6. Explore the function of shear strength properties of backfill such as cohesion and friction in the pipeline flotation problem.
7. Investigate method for determining pullout resistance of mechanical anchors is undisturbed soils.

B. To provide the greatest security and to provide maximum protection against interruption of service during storms and floods, offshore pipelines should be buried.

C. To install unburied submerged lines the anchorage or pipeline weighting criteria should be based on a hydrodynamic study of the proposed location and water forces to which the pipeline may be exposed.

Satisfactory answers to the questions outlined in the proposed research program are needed to complement existing knowledge in order to place the design of submerged pipelines on a truly technical basis. This technical approach to the design of inundated pipelines should result in the most economical solution consistent with safe operation.

This report is respectfully submitted by the Task Committee on Floatation Studies, Committee on Pipeline Installations of the Pipeline Division.

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DISCUSSION

ENGINEER-GEOLOGIST TEAM INVESTIGATES SUBSIDENCE[a]

Discussion by Richard E. Burnett, William W. Moore, Vernon A. Smoots, and David C. Liu

RICHARD E. BURNETT[1], F. ASCE.—An interesting and complex problem has been described by the authors. There are many aspects to the investigation that will require (and are receiving) the attention of civil engineers and other professional people. The broad problem is being attacked by the Inter-Agency Committee with individual problems being attacked by the agencies primarily affected. The concerted efforts of these various groups, each studying the problem from different points of view, will reach suitable explanation of the causes, the ultimate amounts, and the rates of subsidence. Then economic solutions can be developed that will be consistent with the ultimate requirements.

The immediate problem of the Department of Water Resources, as stated in the paper, is the design and construction of an aqueduct across areas of known or suspected "shallow" subsidence. Apparently the "deep" subsidence problem referred to is not considered of major significance because of its more uniform nature of occurrence; and the relatively minor amount of movement attributable to this cause that has been experienced along the westerly edge of the valley.

No mention is made in the paper about the feasibility of locating the aqueduct at a higher elevation in the more consolidated materials of the foothills of the Coast Ranges. Because of the generally steep and rough topography, the foothills area is not attractive as a location for a canal. The volume of water that must be conveyed and the cost of pumping make closed conduits uneconomical for the purpose. It is assumed, therefore, these and other considerations have dictated the location to be in the valley area in which subsidence of the land has and/or will occur.

Insofar as the design and construction of the canal is concerned, the problem areas are stated to have been reasonably well delineated. The cause of "shallow" subsidence has been determined. The means of predicting ultimate amounts and rates of subsidence are at hand or will be as the current experiments are completed. There then remains the problem of determining the most economical method of hastening the consolidation of the foundations for structures to the point at which structures can be built to perform safely and satisfactorily. The time available to complete the necessary consolidation before the completed structures are required for service undoubtedly is limited. Apparently much of the subsidence area through which the aqueduct will be located has never been irrigated but is susceptible of being irrigated

[a] May 1959, by M. J. Shelton and L. B. James (Proc. paper 2073).

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when water becomes available. The lands along the margin of the currently irrigated areas are and have been settling. Therefore, the problem exists of consolidating the lands in areas outside the canal proper as well. It thus would appear that all aspects of hastening areal subsidence in the vicinity of the canal should be considered along with those of associated with design of the aqueduct structures.

The generally impervious nature of the soils or strata of soils prevents rapid introduction of water from the surface to the zones in which consolidation will occur. The time lag at which settlement at increasing depth occurs and the rates of infiltration experienced in the test plots confirm this. The authors state subsidence at depths of 300 ft may not occur for a century. Thus, it appears that complete consolidation of the materials involved cannot be attained in a reasonable time. The depths to groundwater in the "shallow" subsidence areas are not stated. From descriptions contained in the Inter-Agency Committee "Progress Report-Land Subsidence Investigations-San Joaquin Valley, California-Through 1957" (pp 64,65), holes drilled in test plots evidently did not encounter groundwater in the depths drilled. It would be of interest to know the depths to groundwater in the "shallow" subsidence areas. A measure of the volume of water required to accomplish full consolidation thus would be afforded.

Any successful method of consolidating the materials will require complete saturation of the soil. Saturation of the entire soil column at one time may not be necessary, but undoubtedly reaching the major amount of subsidence will thereby be hastened. Of the several methods for hastening subsidence that the authors state will be investigated during the next phase; the writer's opinion is that flooding, either by ponding or by intermittent application of water by irrigation will prove the most practicable. Several of the methods suggested will obviously not work or are not practicable in the soils involved. Injecting water at depth should hasten subsidence, but any method for doing so will be extremely expensive so that its application doubtlessly will be limited to foundations for relatively small major structures.

The methods adopted for hastening subsidence may materially affect the overall project schedule for construction. Considerable preparatory work will be required before the permanent canal can be constructed, and this undoubtedly will be time consuming. Therefore, an early decision on the method appears to be in order.

The profession will profit from the studies now in progress. Periodic reports through the Proceedings of the Society to supplement this informative paper will be welcomed.

Before final solution of this far reaching problem, this writer forecasts that many "teams" of civil engineers and other professional people will have participated.

WILLIAM W. MOORE,[1] F. ASCE, VERNON A. SMOOTS,[2] M. ASCE, and DAVID C. LIU[3].—The authors have called attention to a problem of soil behavior that may be overlooked and can become very serious if it is not properly anticipated. The use of an engineer-geologist team is a most advantageous way to detect the possibility of this type of problem. In fact, this sort of

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coordinated activity should probably be used in many more areas of engineering construction projects than has been customary in the past.

Types of Structures Affected.—The paper was limited to the construction of aqueducts. It should be pointed out that the so-called shallow subsidence can also have serious effects on reservoirs, buildings, industrial plants, and many other types of engineering construction and development. In the discussion of specific condtions in the subsequent paragraphs, data will be presented to indicate cases in which reservoirs and light office buildings were severely affected by settlements resulting from the saturation of soils in arid areas.

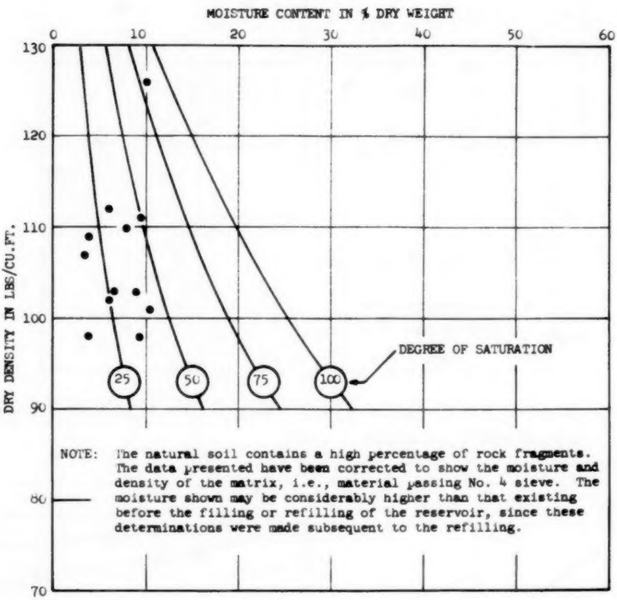

FIG. 1.—MOISTURE & DENSITY DATA, RESERVOIR SITE, HAWTHORNE, NEV.

Types of Soils Susceptible to Subsidence.—The areal subsidence described by the authors is believed to be not always related to mud flow of low density. It is the writers' experience that this type of behavior can occur in uncompacted alluvial fan sediments of a wide range of densities.

Case 1.—In one case, a reservoir was constructed on a soil having matrix dry densities from about 98 lb to 126 pcf. This reservoir, located in the vicinity of Hawthorne, Nevada, was filled with water to a depth of 23 ft, and it was immediately emptied when cracks developed in the compacted fill embankment. After the initial filling and emptying, another attempt was made to use the reservoir. Settlement data were obtained before and after the second filling of the reservoir. These data indicated that the settlement amounted to 1 in. to 3 in. resulting from the refilling of the reservoir to a maximum depth of only five ft.

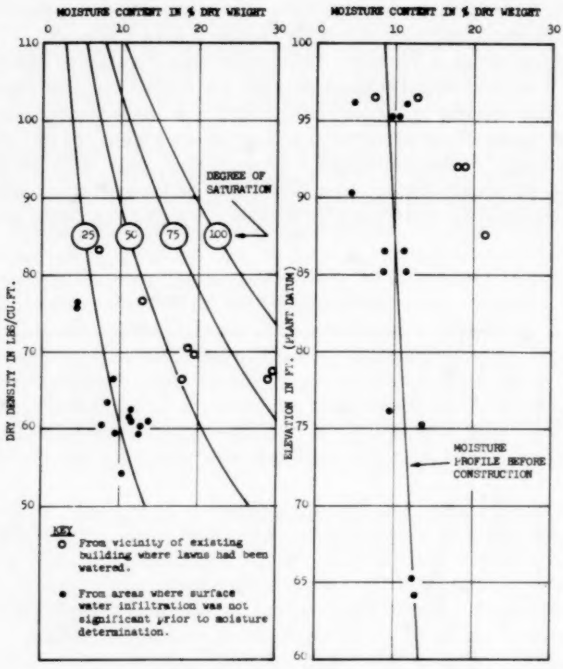

FIG. 2.—MOISTURE & DENSITY DATA, OFFICE BUILDING SITE, WESTERN SAN JOAQUIN VALLEY, CALIF.

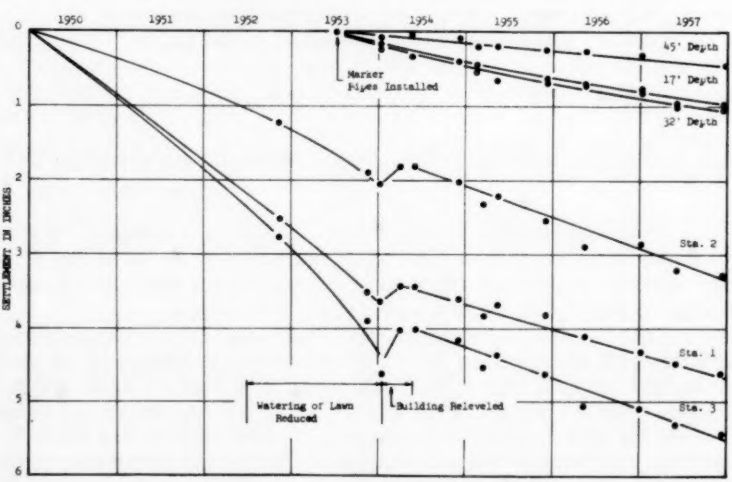

FIG. 3.—SETTLEMENT DATA, OFFICE BUILDING SITE, WESTERN SAN JOAQUIN VALLEY, CALIF.

The natural material at the site consists of alluvial deposits with gravels and cobbles up to several inches in size. The gross density of the material in several samples was in excess of 150 pcf, and the dry density and moisture content of the matrix (material passing No. 4 sieve) were determined by considering the percentage of rock fragments. The moisture and density data after the second filling are presented in Fig. 1. It is likely that the moisture before initial filling was considerably lower. It is interesting to note that,

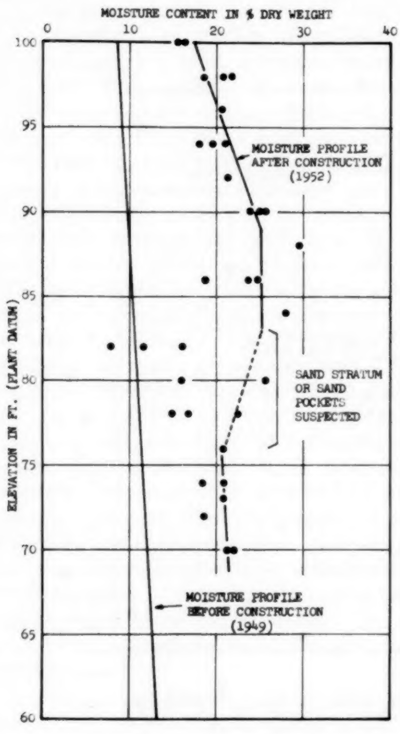

FIG. 4.—MOISTURE DATA, BEFORE & AFTER CONSTRUCTION OFFICE BUILDING SITE, WESTERN SAN JOAQUIN VALLEY, CALIF.

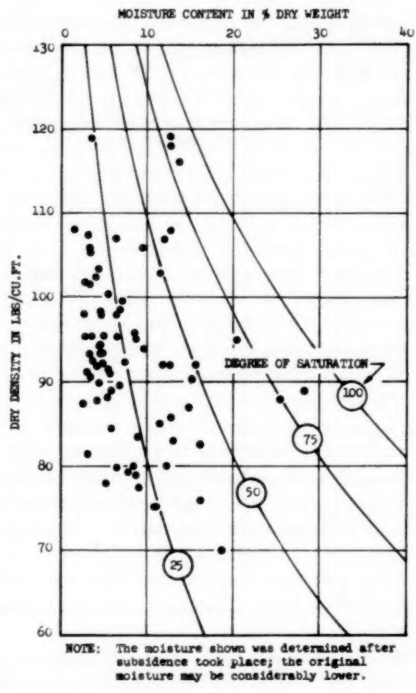

FIG. 5.—MOISTURE & DENSITY DATA, AIRFIELD, SOUTHERN SAN JOAQUIN VALLEY, CALIF.

because of the rather high densities existing in the natural deposits, the owner of this project did not feel it necessary to investigate the foundation conditions even after the subsidence had almost created a failure condition. In fact, it is understood that severe difficulties were encountered in other reservoirs in the same vicinity; yet, the owner's representatives refused to accept the possibility that water infiltration was the principal cause of the settlement.

Case 2.—In another case, a very light one-story office building was constructed in the western part of San Joaquin Valley of California, in an area in which the soil density was generally quite low. In view of the subsidence experienced with other structures in the surrounding area, the building was supported on drilled piles, even though the column loads ranged from 9 kips to only 44 kips. The moisture and density data on the supporting soild are presented in Fig. 2. With only moderate moisture infiltration caused by watering of lawns, the building started to settle as illustrated in Fig. 3. An investigation indicated that the moisture content had increased from about 10% to

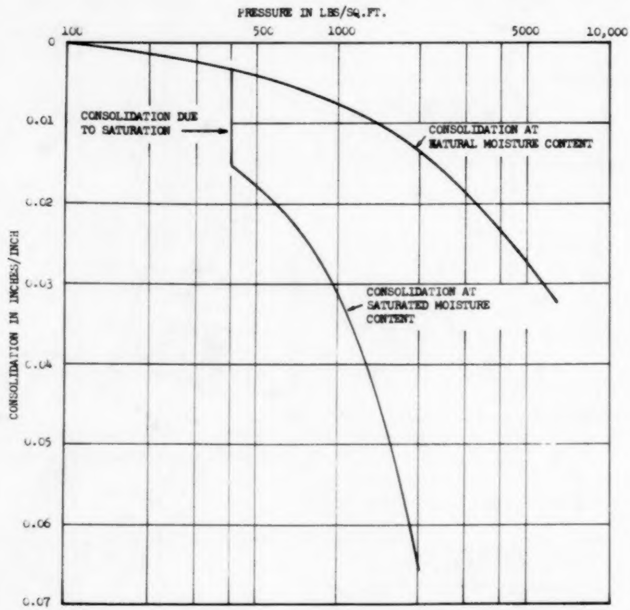

FIG. 6.—CONSOLIDATION DATA, OFFICE BUILDING SITE, WESTERN SAN JOAQUIN VALLEY, CALIF.

over 20% in the area of maximum structural settlement, as shown on Fig. 4. In an attempt to determine the depth of the influence of the surface moistening of arid soils, vertical pipes were installed at various depths in the ground so that the settlements at three levels could be measured. The data obtained are also illustrated on Fig. 3. It is obvious from the settlement data on these pipes that the influence of surface water infiltration was greatest in the upper soils, but it extended to at least 45 ft below the ground surface. This observation supports the data presented on Fig. 8 and 9 of the authors' paper.

Case 3.—In a third case, a number of structures at an airfield in the southern part of the San Joaquin Valley settled badly as a result of surface water infiltration. Among the structures affected are a sewage treatment clarifier, a hangar, and an office building, and the maximum settlement was

about 12 in. at the time of investigation. The soils at this site represent flashflood deposits, and the moisture and density data are presented on Fig. 5. The density is not unusually low, but the moisture content is very low as is typical arid area.

It is noted that in all the cases observed by the writers, the moisture seems to be very low or, more correctly, the degree of saturation is below at least 50%. It has been our experience, however, that solids that are susceptible to severe subsidence due to water infiltration may be identified by laboratory tests, particularly consolidation tests in which water is introduced under a load approximating the natural overburden. In general, soils showing large consolidations in such a consolidation test would undergo considerable subsidence as a result of subsequent saturation in the field. A typical graph showing the results of such consolidation tests is presented as Fig.6.

Preventive Measures.—To limit the damage due to subsidence, presettling by the saturation of an area, in which practical, seems to be the best method available at this time, especially for water-carrying structures. Although actual experience records are quite few, we believe the use of either driven or drilled pile clusters extending to a fairly uniform depth may help to restrict the differential settlement that may be imposed on a structure. Such piling cannot prevent a general subsidence of the area, but it will decrease the differential settlement a structure may experience. It is necessary to seek an economic balance between the cost of long piles and an acceptable settlement behavior. Where the water infiltration is expected to be nonuniform, a slight increase in penetration of the piles in areas of greater infiltration may be attempted to obtain more uniform settlements, although such practice is not subject to precise evaluation. Data available to the writers seem to indicate that the depth of influence from surface infiltration may extend almost indefinitely with time provided a steady supply of surface water is present. However, the severity of the effects seems to decrease at greater depths, because the differential settlement they cause becomes less pronounced. A third precautionary measure has been used for soils that are only moderately susceptible to subsidence due to surface moisture infiltration. This consists of grading and paving the area surrounding a structure to drain water away from the structure. It is the writers' experience that this procedure will be effective only for soils showing moderate sensitivity to moisture infiltration.

Radioactive Testing.—It is also pertinent to observe that the radioactive tests for moisture and density as described by the authors have also been used by the writers' firm in several cases. In general, this method has been found quite useful, particularly when working at appreciable depths below the ground surface. The writers' experience would indicate that the accuracy of the radioactive method was generally within 2% or 3% and almost always within 5%. The equipment available to date has not been as efficient as seems desirable, and probably a substantial amount of development may be necessary to make this equipment readily and economically applicable on the usual run of engineering work.

Summary.—In conclusion, the writers' discussions may be summarized as follows:

1. The subsidence due to water infiltration can occur in various types of arid sediments and not only in mud flows. This behavior can affect various kinds of structures or buildings even when substantial quantities of water storage are not involved in the project.

2. In general, a low degree of saturation indicates the possibility of subsidence due to subsequent water saturation. A low density tends to indicate possible high magnitude of subsidence; on the other hand, a high gross density may not indicate that the soils are stable. Adverse behavior can occur in very sandy and gravelly soils as well as in fine-grained soils. It is believed that laboratory data on consolidation due to saturation under appropriate test pressures are the most positive identification of soils exhibiting this behavior.

3. There is no complete cure for this adverse behavior. If practical, presettling by saturation may be used. For structures in limited areas, the use of piling of substantial length and possibly uniform length throughout the structure may be helpful to restrict, but not to eliminate, differential settlements. Also, proper grading and paving may be used in certain less sensitive soils to reduce the possibility of excessive subsidence.

REGULATION OF PIPELINE DESIGN AND CONSTRUCTION[a]

Discussion by Raymond H. Crowe, Steve R. Sawyer, and John Randall

RAYMOND H. CROWE[1].—The listing of the number of states that the American Standards Association (ASA) B.31.1.8 as a state code with minor exceptions is gratifying. The number of states that have adopted the code with modification points out the need for continued education of the state bodies.

The emphasis that many of the states put on casing requirements shows the need for the American Society of Civil Engineers (ASCE) Task Committee on Highway and Railroad Casings. There seems to be an opinion that casing of pipe lines materially adds to the safety of the pipe line that in the opinion of many engineers is not necessarily true. Casings were originally installed by pipeline companies as a matter of convenience rather than as a means of increasing safety. The ASCE task committee may be able to clarify this matter.

It is noted that the New Jersey requirements[2] are not up to date, because Administrative Order 14.295 has been adopted that now follows the latest ASA code with certain modifications. It is believed that this is also true in the case of New York State.

STEVE R. SAWYER[1].—The abstract is a resume of various provincial acts covering design, construction, and operation of pipe lines in the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba, in Canada.

These provincial acts have been in existence for a relatively short period of time and, perhaps, should be reviewed regularly so as to enable anyone to maintain the abstract up to date. It would appear that the various regulations may be expanded to incorporate and reflect conditions peculiar to the various provinces.

Just this year (1960) the Province of Ontario, through the Ontario Fuel Board, has enacted a Gas Transmission and Distribution Pipe Line Code. This code is 40 pages in length with the greater part of it based on ASA B31.8-1958. The section of the Ontario Code covering the testing of welders, welding techniques, and so forth, is set out in greater detail than other sections of this code.

[a] October, 1959, by the Task Committee on Investigation of Problems Involved in Regulation of Pipeline Design and Construction by Various Governmental Agencies (Proc. paper 2204).

[1] Chf. Engr., Transcontinental Gas Pipe Line Corp., Houston, Tex.

[2] "Bibliography on Pipeline Design, Construction Second Progress Report of the Task Committee on Investigation of Problems Involved in Regulation of Pipeline Design and Construction by Various Governmental Agencies of the Committee on Pipeline Planning of the Pipeline Division.

[1] Chf. Engr., Trans-Canada Pipe Lines Ltd., Toronto 12, Ontario, Canada.

The following is a synopsis of the Pipe Lines Act - 1958 for the Province of Ontario similar to the other four provinces covered by the abstract:

1. Obtain approval from Fuel Board to construct pipe line. Application must be accompanied by an alignment sheet.
2. Easement forms to be approved by Fuel Board.
3. Right to expropriate after application granted.
4. Board's authority necessary to construct under highways, railways, and other buried utilities.

Each of the provincial regulations applies only to pipelines operated wholly within the boundaries of the particular province. Pipelines transmitting hydrocarbons across provinces and international boarders are considered interprovincial and fall under the jurisdiction of the Dominion Government and are regulated by the National Energy Board.

The National Energy Board was created in 1959, and to date (February, 1960) they have no detailed pipeline design and construction code or regulations. However, they will be issuing regulations in the near future.

JOHN RANDALL[2].—State regulation of design, construction, and operation of high pressure gas transmission pipelines in California is proposed by the California Public Utilities Commission (PUC). A draft of proposed regulations prepared by the commission staff has been submitted in public hearing before a commission examiner to allow discussion by interested parties and to obtain the recommendations of affected utilities.

The California Public Utilities Commission contends that the need for regulation of gas transmission pipeline design in California has developed from the rapid growth of population and the increasing hazard to public safety incident to multiplying high pressure gas transmission facilities within the state.

Under CPUC Case No. 6352, the "Proposed General Order - Rules Governing Design, Construction, Testing, Maintenance and Operation of Gas Transmission Pipeline Systems," as prepared by the Commission Staff, was presented at public hearings held in San Francisco October 13, 1959, and January 18 through 22, 1960.

The scope of the proposed general order was intended to cover all phases of the work related to construction and operation of gas transmission pipelines.

Specific requirements were outlined under the following chapter headings:

(a) General Provisions: presenting the purpose, scope and intent of the rules, the order of precedence, means for modification, requirement for standards and specifications, and definitions.

(b) Materials and Equipment: establishing the qualification of such items for the work.

(c) Design: covering location class, protection, corrosion, casings, branch connections, expansion, supports and location limitations.

(d) Construction: covering construction materials and equipment, specifications for construction, and limitations on construction practices.

(e) Welding: outlining required specifications for welding procedures, qualification of welders, and welding inspection.

(f) Purging: covering initial gas filling, temporary removal, and abandonment.

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[2] Civ. Engr., So. Calif. Edison Co., Los Angeles, Calif.

(g) Testing and Inspection: outlining requirements for strength, leakage and coating tests, and for excavation, pipe, welding and backfill inspection.

(h) Operation and Maintenance: outlining the requirements for operation and maintenance procedures.

(i) Miscellaneous: covering odorization procedures and requirements.

(j) Reports: establishing the responsibility for maintenance of records, and filing of reports relative to changes in pipeline facilities.

Nine appendices were included, covering bending properties of pipe, longitudinal joint factor, qualification of welders, design formula, yield strength of pipe steel, wall thickness of pipe, design factor, temperature factor, and allowable construction types.

During the hearings, considerable evidence was presented by representatives of three California gas companies, indicating that the field covered by the text of the general order proposed by the commission staff was adequately covered by the American Standards Association Code B31.8-58. With some modifications to make certain requirements of the ASA Code mandatory instead of permissive, Code B31.8 could be adopted by the State for pipeline regulation purposes, thereby conforming with widely accepted existing standards.

Testimony by Mr. F. S. G. Williams, Chairman of the ASA Sectional Committee on Code for Pressure Piping (B31), and several ASA publications that were introduced as evidence, pointed out the great amount of time and effort spent by experts in developing, editing, and finally producing Code B31.8.

The stand taken by another California gas company was a general acceptance of the form of the general order proposed by the commission staff, but with specific modifications where they considered the requirements to be inadequate or incompatible with present-day construction practices.

Two gas companies and the Los Angeles Department of Public Utilities and Transportation recommended that the proposed General Order should include gas distribution pipelines as well as transmission pipelines, because of the interchangeability of function of some large pipelines designed to operate at hoop stresses of 20% or more of the specified minimum yield strength of the pipe.

The fact has been accepted generally that standardization of various industrial practices is desirable. The construction and operation of high pressure gas pipelines are industrial practices that fall within a category subject to standardization. The ASA Code B31.8 for gas transmission and distribution piping systems is subject to periodic updating (3 yr period) to keep it current with technological developments and changing requirements. In view of the wide extent of gas pipeline construction, both interstate and international, it seem logical that a carefully developed standardized code, such as ASA Code B31.8, would serve the best interests of the public.

BIBLIOGRAPHY ON PIPELINE DESIGN, CONSTRUCTION AND OPERATION[a]

Discussion by Donald Van Sickle

DONALD VAN SICKLE,[1] A. M. ASCE.—As stated in the introduction, the purpose of the task committee is to develop a bibliography of reference materials on the design, construction, and operation of pipeline facilities. A really complete bibliography of this type would be of considerable value to all pipeline engineers. Needless to say, the work involved in such a compilation assumes monumental proportions. When one begins a listing of the books, bulletins, articles, pamphlets, and so forth, on even one small phase of the pipeline field, it becomes apparent that the committee's remark that "the material is. . .voluminous. . ." is so restrained as to be almost a gross understatement.

In view of the tremendous volume of published material, the committee apparently plans to approach the problem by listing only the various professional organizations and industry associations that publish the material, the libraries and indices that contain or index the material, together with a selected list of individual books, bulletins, articles, and papers. The committee proposes to publish this information periodically in the Journal of the Pipeline Division and to ultimately publish the complete work as a Technical Manual.

The writer feels that there are a number of shortcomings in this approach to the problem that could seriously hamper the effectiveness and the value of the bibliography and that merit some discussion.

1. Because "no attempt is made to list all papers, articles and books" it is unfortunate that any were listed. Such a partial listing should include the most valuable and significant references, and the decisions as to which are the most valuable and significant would always be open to question. Although there is little doubt that an attempt to list all references could not be completely successful, the committee's plan for periodic publication of the information is admirably suited to achieving the most complete listing possible, because readers could supply additional references that were unknown to the committee, and eventually a virtually complete listing could be achieved.

2. If no complete listing of books, articles, and papers is attempted, the list of professional organizations, industry associations, libraries and indices, and a partial listing of publications, although of some reference value, would hardly seem to merit publication as a technical manual.

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[a] October, 1959, by the Task Committee on Compilation of Bibliography of Reference Materials on Pipeline Design and Construction of the Committee on Pipeline Design, Specifications and Operating Standards of the Pipeline Division (Proc. paper 2205).

[1] Hydr. Engr., Turner and Collie Cons. Engrs., Inc., Houston, Tex.

3. Closely allied with the problem of complete or partial listing of individual papers is the problem of listing papers appearing in foreign publications. One difficulty with such publications is that ordinarily they are not readily accessible to engineers in the United States. Another difficulty is that, even where accessible, those published in languages other than English present translation problems. A number of the more significant works, particularly in French and German, have been translated by various individuals and organizations, but certainly these represent a very small proportion of the total of foreign language references.

In view of these difficulties, should such foreign publications, whether in English or another language, be listed in the proposed bibliography? The writer feels that a complete bibliography would require inclusion of foreign references, although he recognizes that listing of such foreign references would tend to be less complete than a listing of references to works in English.

At first glance, it would appear that the committee chooses to neglect any foreign references, because there are no non-American listings in the sections on "Professional Organizations," "Industry Associations," "Libraries and Indices," and "General." However, inclusion of references to at least six foreign-published articles and books in the "Books and Bulletins" section indicates that the committee feels certain publications could not be excluded. Certainly the works of Manning, Reynolds, and Prandtl should be included in any listing of references on flow of fluids in pipes, even though their original publications are not readily accessible to the average engineer.

4. The writer questions the listing of Association of American Railroads, the Manufacturers Standardization Society of the Valve and Fitting Industry, and the National Fire Protection Association as "Professional Organizations" when they would seem to more nearly fall in the category of "Industry Associations." In fact, some engineers maintain that even the American Water Works Association and The Federation of Sewage and Industrial Wastes Associations (now the Water Pollution Control Federation) are "trade associations" rather than professional organizations, because much of their membership consists of plant operators who are not qualified as professional engineers.

The above comments are certainly not intended to detract from, or belittle, the work of the committee. They are primarily intended to point out that clearer definition of the scope of the bibliography, as well as of terms such as "Professional Organizations" and "Industry Associations" will be required before actual listing of references is undertaken.

The writer would prefer that the Committee plan to make this bibliography as complete as possible, including foreign references, so that it will be worthy of publication as a technical manual. In this connection, a more detailed breakdown of the reference listings under various subject headings would seem to be much superior to listings under "Books and Bulletins" and "General." These headings might include standards and specifications; structural design; hydraulic design; mechanical design; construction; operation and maintenance of lines; operation and maintenance of pumps and compressors; and so forth. Further subdivisions under these main headings would probably be advisable. For instance, under hydraulic design could be included flow of fluids in pipes; losses in valves and fittings; surge and water hammer; and so forth.

Because the bulk of the material is published by organizations such as (ASCE), the American Society of Civil Engineers, that also publish annual and periodic indices, a large portion of the compilation work could be accomplished

fairly rapidly by referring to these indices. The fact that the material is usually listed under headings and subheadings similar to those above is worthy of mention.

After publication of the bibliography as an annual, technical manual or at least regular publication, supplements should be issued to keep it up-to-date. This procedure is followed by the United Kingdom's Institution of Civil Engineers with their Bibliography on Prestressed Concrete and Bibliography on Soil Mechanics, apparently with considerable success.

The following organizations publish, at various times, articles on pipelines and should be included in the bibliography.

(1) The Engineering Institute of Canada, The Engineering Journal and Transactions, 2050 Mansfield Street, Montreal 2, Quebec, Canada.

(2) The Institution of Civil Engineers, Proceedings, Great George Street, Westminster, London, S.W. 1, England.

(3) The Institution of Water Engineers, Journal, Parliament Mansions, Abbey Orchard Street, London, S.W. 1, England.

(4) The Institution of Mechanical Engineers, Proceedings, 1 Birdcage Walk, London, S.W. 1, England.

(5) The International Water Supply Association, Aqua, and Proceedings of triennial congresses, 34 Park Street, London, W. 1, England.

(6) The Hydraulics Research Station of the Department of Scientific and Industrial Research, Hydraulics Research Papers and Annual Reports, Howbery Park, Wallingford, Berkshire, England.

(7) The Hydraulic Institute, Standards, 122 East 42nd St., New York 17, N.Y.

There are certainly many others.

In conclusion, the writer wishes to congratulate the committee for their efforts, and looks forward to the ultimate production of the technical manual as a significant contribution to pipeline engineering.

NON CYLINDER PRESTRESSED PIPES[a]

Discussion by J. Hasker

J. HASKER[1].—The author suggests that prestressed concrete pipes are structurally suitable for sizes ranging from 1 ft internal diameter to several feet. There is no reason why the process is not structurally suitable for pipes less than 1 ft in diameter, but it is doubtful if the process is economically suitable for small diameter pipes in many cases. The upper limit of diameter is also governed by the economic question and non cylinder prestressed pipes are in use in France having a diameter of 16 ft 6 in.

Pipes having an internal diameter of 33 in. are in use in Australia; these pipes are non cylinder prestressed concrete and test pressures were up to 435 psi. and as far as the process is concerned, there is no reason why pipes should not be made for higher pressures.

The author's consideration is sound until he considers the combined effect of internal and external loads. As authorities frequently disagree about the methods of combining these loads, it is advisable to avoid any possible cause of difference of opinion. Criticism that could be levelled at the theory as stated are as follows:

1. With a well laid and bedded pipeline, the effect of external loads is very small. Earth covers of any magnitude would occur infrequently and except at these points can usually be neglected. Pipelines for water supply follow the contours as far as possible and a cover of 20 ft would be unusual.

2. Some authorities may query the magnitude of the axial force at the invert. In any case, the equivalent area of the wound wire should be added to the concrete area to find the stress due to the force.

3. No mention is made of the tensile stress due to the external loads. These are important, more so than the compressive stresses. Concrete in-well made cores has an ultimate strength of 8,000 psi to 10,000 psi at 28 days, and compressive stresses due to design loads would seldom reach 50% of this strength, and stresses due to working loads would be even less. The pressure is not zero in practice, therefore, the nett direct compression due to the winding and the working pressure will be considerably less than the stated 1,720 psi.

Consideration of combined direct and bending stresses in concrete always introduces the uncertainty of how the stresses should be added. Apparent extreme fibre stresses at failure in bending are considerably higher than direct tension stresses at failure; and ratio varies approximately between 1.6 and 2.1, and merely adding the two stresses would not give the true stress under

[a] October 1959, by S. R. Hubbard (Proc. paper 2240).

[1] Chf. Engr., Rocla Pipes Ltd., Melbourne, Australia.

the combined loads. The late Gustav Magnel used a factor varying between 1.9 and 2.6 and divided the extreme fibre stress due to bending by a selected value before adding to the direct stresses due to winding and pressure. This method, although not necessarily correct, gives a more accurate result than the direct addition.

4. No mention is made of the effect of the cost in resisting external and internal loads. The additional resistence due to coat is obviously used as an additional factor of safety but this fact should be mentioned. The combined behavior of core and coat is most satisfactory with well made pipes, and it is probable that the coat effect should be considered, at least when computing stresses due to external loads.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 2703 is identified as 2703(ST1) which indicates that the paper is contained in the first issue of the Journal of the Structural Division during 1961.

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FEBRUARY: 2355(CO1), 2356(CO1), 2357(CO1), 2358(CO1), 2359(CO1), 2360(CO1), 2361(PO1), 2362(HY2), 2363(ST2), 2364(HY2), 2365(SU1), 2366(HY2), 2367(SU1), 2368(SM1), 2369(HY2), 2370(SU1), 2371(HY2), 2372(PO1), 2373(SM1), 2374(HY2), 2375(PO1), 2376(HY2), 2377(CO1)[c], 2378(SU1), 2379(SU1), 2380(SU1), 2381(HY2)[c], 2382(ST2), 2383(SU1), 2384(ST2), 2385(SU1)[c], 2386(SU1), 2387(SU1), 2388(SU1), 2389(SM1), 2390(ST2)[c], 2391(SM1)[c], 2392(PO1)[c].

MARCH: 2393(IR1), 2394(IR1), 2395(IR1), 2396(IR1), 2397(IR1), 2398(IR1), 2399(IR1), 2400(IR1), 2401(IR1), 2402(IR1), 2403(IR1), 2404(IR1), 2405(IR1), 2406(IR1), 2407(SA2), 2408(SA2), 2409(HY3), 2410(ST3), 2411 (SA2), 2412(HW1), 2413(WW1), 2414(WW1), 2415(HY3), 2416(HW1), 2417(HW3), 2418(HW1)[c], 2419(WW1)[c], 2420(WW1), 2421(WW1), 2422(WW1), 2423(WW1), 2424(SA2), 2425(SA2)[c], 2426(HY3)[c], 2427(ST3)[c].

APRIL: 2428(ST4), 2429(HY4), 2430(PO2), 2431(SM2), 2432(PO2), 2433(ST4), 2434(EM2), 2435(PO2), 2436 (ST4), 2437(ST4), 2438(HY4), 2439(EM2), 2440(EM2), 2441(ST4), 2442(SM2), 2443(HY4), 2444(ST4), 2445 (EM2), 2446(ST4), 2447(EM2), 2448(SM2), 2449(HY4), 2450(ST4), 2451(HY4), 2452(HY4), 2453(EM2), 2454 (EM2), 2455(EM2)[c], 2456(HY4)[c], 2457(PO2)[c], 2458(ST4)[c], 2459(SM2)[c].

MAY: 2460(AT1), 2461(ST5), 2462(AT1), 2463(AT1), 2464(CP1), 2465(CP1), 2466(AT1), 2467(AT1), 2468(SA3), 2469(HY5), 2470(ST5), 2471(SA3), 2472(SA3), 2473(ST5), 2474(SA3), 2475(ST5), 2476(SA3), 2477(ST5), 2478 (HY5), 2479(SA3), 2480(ST5), 2481(SA3), 2482(CO2), 2483(CO2), 2484(HY5), 2485(HY5), 2486(AT1)[c], 2487 (CP1)[c], 2488(CO2)[c], 2489(HY5)[c], 2490(SA3)[c], 2491(ST5)[c], 2492(CP1), 2493(CO2).

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JULY: 2541(ST7), 2542(ST7), 2543(SA4), 2544(ST7), 2545(ST7), 2546(HY7), 2547(ST7), 2548(SU2), 2549(SA4), 2550(SU2), 2551(HY7), 2552(ST7), 2553(SU2), 2554(SA4), 2555(ST7), 2556(SA4), 2557(SA4), 2558(SA4), 2559(ST7), 2560(SU2)[c], 2561(SA4)[c], 2562(HY7)[c], 2563(ST7)[c].

AUGUST: 2564(SM4), 2565(EM4), 2566(ST8), 2567(EM4), 2568(PO4), 2569(PO4), 2570(HY8), 2571(EM4), 2572(EM4), 2573(EM4), 2574(SM4), 2575(EM4), 2576(EM4), 2577(HY8), 2578(EM4), 2579(PO4), 2580 (EM4), 2581(ST8), 2582(ST8), 2583(EM4)[c], 2584(PO4)[c], 2585(ST8)[c], 2586(SM4)[c], 2587(HY8)[c].

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OCTOBER: 2615(EM5), 2616(EM5), 2617(ST10), 2618(SM5), 2619(EM5), 2620(EM5), 2621(ST10), 2622(EM5), 2623(SM5), 2624(EM5), 2625(SM5), 2626(SM5), 2627(EM5), 2628(EM5), 2629(ST10), 2630(ST10), 2631(PO5)[c], 2632(EM5)[c], 2633(ST10), 2634(ST10), 2635(ST10)[c], 2636(SM5)[c].

NOVEMBER: 2637(ST11), 2638(ST11), 2639(CO3), 2640(ST11), 2641(SA6), 2642(WW4), 2643(ST11), 2644(HY9), 2645(ST11), 2646(HY9), 2647(WW4), 2648(WW4), 2649(WW4), 2650(ST11), 2651(CO3), 2652(HY9), 2653(HY9), 2654(ST11), 2655(HY9), 2656(HY9), 2657(SA6), 2658(WW4), 2659(WW4)[c], 2660(SA6), 2661(CO3), 2662(CO3), 2663(SA6), 2664(CO3)[c], 2665(HY9)[c], 2666(SA6)[c], 2667(ST11)[c].

DECEMBER: 2668(ST12), 2669(IR4), 2670(SM6), 2671(IR4), 2672(IR4), 2673(IR4), 2674(ST12), 2675 (EM6), 2676(IR4), 2677(HW4), 2678(ST12), 2679(EM6), 2680(ST12), 2681(SM6), 2682(IR4), 2683(SM6), 2684(SM6), 2685(IR4), 2686(EM6), 2687(EM6), 2688(EM6), 2689(EM6), 2690(EM6), 2691(EM6)[c], 2692 (ST12), 2693(ST12), 2694(HW4)[c], 2695(IR4)[c], 2696(SM6)[c], 2697(ST12)[c].

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JANUARY: 2698(PP1), 2699(PP1), 2700(HY1), 2701(SA1), 2702(SU1), 2703(ST1), 2704(ST1), 2705(SU1), 2706 (HY1), 2707(HY1), 2708(HY1), 2709(PO1), 2710(HY1), 2711(HY1), 2712(ST1), 2713(HY1), 2714(PO1), 2715 (ST1), 2716(HY1), 2717(SA1), 2718(SA1), 2719(SU1)[c], 2720(SA1)[c], 2721(ST1), 2722(PP1)[c], 2733(PO1)[c], 2724 (HY1)[c], 2725(ST1)[c].

FEBRUARY: 2726(WW1), 2727(EM1), 2728(EM1), 2729(WW1), 2730(WW1), 2731(EM1), 2732(SM1), 2733(WW1), 2734(SM1), 2735(EM1), 2736(EM1), 2737(PL1), 2738(PL1), 2739(PL1), 2740(PL1), 2741(EM1), 2742(ST2), 2743(EM1), 2744(WW1), 2745(WW1), 2746(SM1), 2747(WW1), 2748(EM1), 2749(WW1), 2750(WW1)[c], 2751 (EM1)[c], 2752(SM1)[c], 2753(PL1)[c], 2754(ST2)[c], 2755(PL1).

c. Discussion of several papers, grouped by divisions.